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DEVELOPMENT AND APPLICATION OF COMPUTER SOFTWARE TECHNIQUES TO HUMAN FACTORS TASK DATA HANDLING PROBLEMS

A. T. TULLEY
G. R. MEYER
R. G. OLLER
P. J. MITCHELL
S. E. REARDON

System Development Corporation

and

L. E. REED

Air Force Human Resources Laboratory

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FOREWORD

This report was prepared by the Technical Information Systems Department of System Development Corporation for the Training Research Division of the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. A. T. Tulley of the System Development Corporation was the principal investigator. The research was conducted under Contract F33615-67-C-1036 during the period 1 July 1967 through 27 September 1968. Prior to the establishment of the Air Force Human Resources Laboratory on 1 July 1968, the Training Research Division was an element of the Aerospace Medical Research Laboratories.

The research was conducted in support of Project 1710, "Human Factors in the Design of Training Systems," and Task 171006, "Personnel, Training and Manning Factors in the Conception and Design of Aerospace Systems." Dr. Gordon Eckstrand (HRT) was the Project Scientist and Mr. Melvin T. Snyder (HRTR) was the Task Scientist. Mr. Lawrence E. Reed (HRTR) served as the contract technical monitor.

This report, a companion to AMRL-TR-66-200, "Development and Application of Computer Software Techniques to Human Factors Task Data Handling Problems," represents a part of a total effort directed to the development of techniques for handling human factors task data. Other reports in the series are cited in Section I of this report.

The authors wish to thank the many government and contractor personnel who contributed valuable suggestions throughout the course of this research. Special thanks are due Mr. Melvin T. Snyder, who assisted in the review of the manuscript and Mrs. Joan C. Robinette for her editorial assistance. Acknowledgement is also made to other System Development Corporation personnel: Messrs. A. S. Cooperband, R. Danchick, S. Fisher, Theodore Hamlet, H. Manelowitz, H. Sapan and J. E. Wimberley who served as advisors and technical consultants during the period covered and Mr. Donald E. Blair who edited this report.

This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, PhD.
Chief, Training Research Division
Air Force Human Resources Laboratory

ABSTRACT

Research leading to the application and implementation of techniques for computer handling of human factors task data generated in support of aerospace system development programs is discussed. The technique development is based on the assumption that a user-oriented computerized data handling system will help draw human factors specialists closer to needed data. The application of these techniques should reduce the problem of data accessibility and allow more effective use of data in the system design and development process. A computerized data handling system to store, selectively retrieve, and process human factors data in a user-oriented environment was implemented through a Pilot Study Experimental System (PSES). This experimental system provided the primary means for evaluating the research results. This report discusses the development process of the PSES, the computer software used by the PSES, data classification techniques, and vocabulary controls. Consideration is also given to the feasibility of providing (1) analytic and simulation tools in a user-oriented environment, (2) current awareness notification of data entries, and (3) an advanced and sophisticated classification scheme for identifying functional relationships.

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OVERVIEW OF THE PROBLEM

The importance of ensuring early human factors considerations in the design of aerospace systems has long been recognized by both government and industrial specialists. The ever increasing complexity of today's advanced systems demands that human performance considerations be an integral part of the overall system performance. While government agencies have instituted various programs to ensure proper consideration of the human element, e.g., the Personnel Subsystem program in the Air Force, the sheer speed of system development has placed an almost impossible burden on human factors specialists. Both the amounts of information generated and the compressed system development schedules have led the specialist to rely heavily on his own expertise when data are not known to exist or are inaccessible. As a result, the input to early identification of human factors requirements and the integration of these requirements into system design have not been satisfactory.

The research reported here was designed to study ways to alleviate some of these problems through the application of computer technology. The techniques explored in this research program are based on the assumption that a user-oriented, computer based, data handling system will help draw human factors specialists closer to needed data and that the application of such a system will help reduce the problem of data accessibility and allow more effective use of data in the system design and development process.

RESEARCH GOALS

The research goals are directed toward the development of techniques that will aid the human factors specialist, both in government and industry, to improve the effectiveness of data in the development process of systems. These goals are:

- Provide a means by which data can be accessed when and where they are needed
  The data system must provide rapid access to information on personnel and training requirements, facilities, equipment, and other task related information generated at any point in the development cycle of systems.

- Provide data for any part of a system duplicated in past systems or current systems
  This goal is directed to alleviating the problem of duplicate generation of data. Information generated in support of one system should be available for making decisions on new systems.

- Provide a store of data from which the user may retrieve selectively
  This goal is meant to alleviate the problem of accessing the increasing volume of data generated in support of systems. At any point in time, the

specialist is usually interested in obtaining particular data or combinations of data and nothing else.

- Provide data that are current and frequently updated
  If the time required to avail the user of needed information is greater than the time it takes for information to change, then the information in the data system, though important to applications or other systems, may be inadequate for immediate use. Since the data generated in support of systems have a rapid decay rate, the data user must be provided with the latest information as quickly as possible.

- Provide basic analytic tools
  Rather than force the user to apply specific analytic techniques to his data, the data sytsem should allow the user to select from a pool of existing analytic routines, or simultaneously write and operate new analytic routines that meet his need.

- Provide a standard language without undue constraint on the user
  Technical terms describing human behavior are usually ambiguous and redundant. Some means of vocabulary control must be provided so that data may be retrieved consistently by different users.

RESEARCH APPROACH

Figure 1 illustrates the research activities leading to the application and implementation of computer techniques for handling human factors task data generated in support of aerospace system development programs. The activities are grouped into three areas of study, viz., Preliminary Research, Pilot Study, and Pilot Study Experimental System (PSES).

Preliminary Research

The objective of the preliminary research was to identify problem areas and to determine the feasibility of developing improved methods for handling human factors task data. It was recognized early in the research program that techniques for data handling must be developed in context with the total environment in which they are to operate. Knowledge about the types of data to be handled, the needs of generators and users of data, and the needs for data handling is a prerequisite to the design of such a system. Thus, before recommendations for developing specific techniques could be made, the research was directed to the fulfillment of the following objectives:

- Identify the representative groups of technical and professional specialists involved in the generation and use of human factors task information

- Identify the types and classes of data generated, used, and required by the government and its contractors in system design, development, and operation

- Identify the relationships between data categories, the input/output characteristics of the data, and the various phases in system development under which the data are generated and used

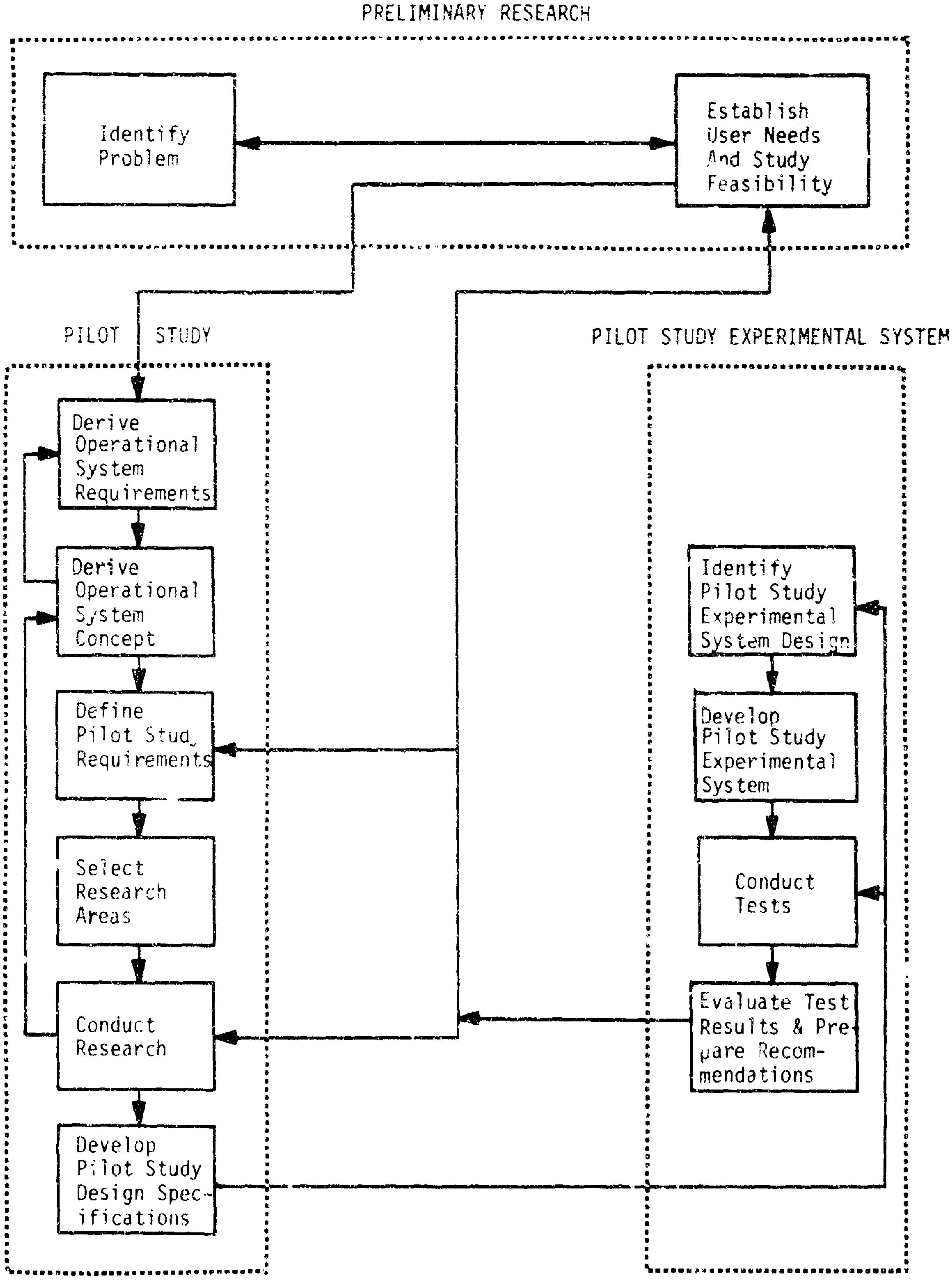


Figure 1. Research Approach

- Describe the uses of the data in making system design, development, operation and related management decisions

- Assess the types of current and potential uses of computers for handling system data

- Assess the current and desired data retrieval times

- Recommend the desired characteristics for a technical data handling system to operate in a government/contractor environment

In response to the preceding objectives, information was gathered through an extensive review of the literature, interviews with pertinent government and industry personnel, and from responses to questionnaires.

The results of the preliminary research are reported in:

Hannah, L. D.; Boldovici, J. A.; Altman, J. W.; and Manion, R. C. The Role of Human Factors Task Data in Aerospace System Design and Development, AMRL-TR-65-131 (AD 621 379).

Hannah, L. D. and Reed, L. E. Basic Human Factors Task Data Relationships in Aerospace Systems Design and Development, AMRL-TR-65-231 (AD 630 638).

Whiteman, I. R. The Role of Computers in Handling Aerospace Systems Human Factors Task Data, AMRL-TR-65-206 (AD 631 182).

Pilot Study

The objectives of the initial study effort beyond the preliminary research was to define requirements and develop techniques for the computerized handling of human factors task data. Research was divided into six distinct efforts (see figure 1): (1) Derive Operational System Requirements; (2) Derive Operational System Concept; (3) Define Pilot Study Requirements; (4) Select Research Areas; (5) Conduct Research; and, (6) Develop Pilot Study Design Specifications.

The results of the initial research are reported in:

Potter, K. W.; Tulley, A. T.; and Reed, L. E. Development and Application of Computer Software Techniques to Human Factors Task Data Handling Problems, AMRL-TR-66-200 (AD 647 993).

Derive Operational System Requirements

An extensive review of the recommendations, information, and experience resulting from the preliminary research led to the determination of 14 requirements for the development of an operational data handling system. These requirements provided the guidelines for the pilot study research and for the development of an experimental system. The requirements are:

(1) The system must be oriented to user requirements. It must satisy the needs of aerospace scientists and engineers and must fulfill management needs for data.

(2) The system must provide for the storage, updating, and retrieval of human factors task data. The data should be indexed to permit retrieval based on several reference points.

(3) The data system must be responsive to current Air Force and National Aeronautics and Space Administration (NASA) system and data management concepts. Compatibility, rather than dependability, with the system engineering process is recommended.

(4) The system must provide simplicity of use by accepting and outputting data in a form approaching user terminology. All inputs and outputs must be immediately interpretable by the user. This includes all data, whether they are qualitative or quantitative in nature.

(5) The user of the data system must have easy access to the stored data through the use of a user-oriented query language. The terminology interpreted by the system must be compatible with the language employed by the user in his system-specific activity.

(6) Provisions must be made for external storage of data that cannot be coded economically for computer storage. Where applicable, cross-indexed data should be stored in the computer for referencing information filed externally, e.g., documents, pictures and graphs.

(7) The data bank structure must be flexible enough to allow for future expansion and inclusion of additional data elements--categories of information. This flexibility will allow for changes in data concepts and new system requirements and avoid major changes in the structure of the data base.

(8) The data bank must be capable of frequent updating while retaining selected data for such uses as design trend analysis. The system must be capable of purging unwanted historical information. The updating capability of the system should allow for the storage of information generated in support of on-going phases of an aerospace system life cycle.

(9) The data system must be capable of retrieving similar information generated in support of different aerospace systems. This capability will allow maximum use of data in making design decisions for new systems.

(10) The data system must be capable of selectively retrieving data elements by qualifying them with other data elements. With this capability, the user receives only the data he needs and nothing else.

(11) The data system must have the capability of protecting data having security classification and/or proprietary status.

(12) The data system must provide the capability of processing retrieved data through the use of analytic programs and simulation models with a minimum of human intervention.

(13) The system must provide the user freedom in specifying the format of outputs.

(14) The system must provide for current awareness notifications to qualified users, in response to interest profiles. A notification is defined as a statement (via teletype) that data meeting the requirements of a qualified user have been added to the information store.

Derive Operational System Concept

A concept of an operational system for handling and processing aerospace system human factors data in a government/industry environment was developed to lend a realistic context to the research (Reed and Wise, 1965). The concept was derived from the preceding operational system requirements and was used to assist in identifying problems for research.

A brief description of this concept is presented next.

Figure 2 illustrates the conceptualized operating system in an Air Force environment. The Data Exchange Center is the heart of the system which consists of computer hardware, computer programs, data storage, and a data control group.

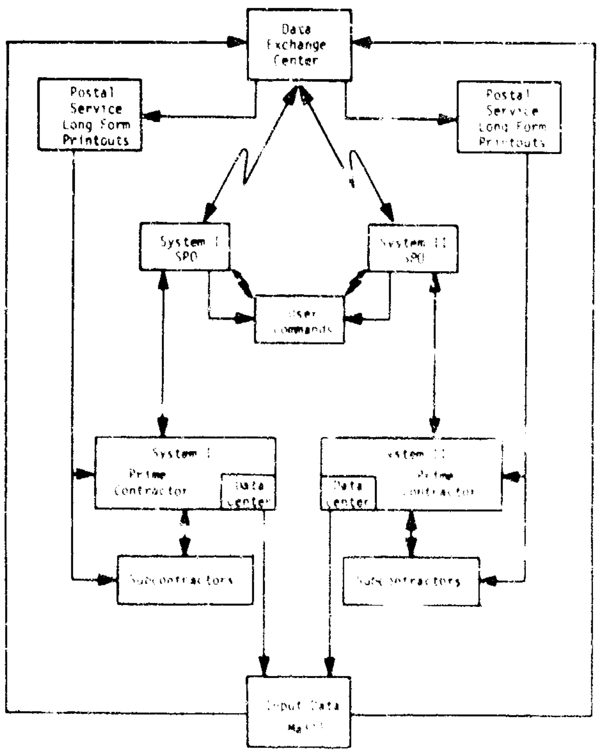


Figure 2. Conceptualized Operating System

For purposes of discussion, it will be assumed that a data exchange center is located at an Air Force Systems Command (AFSC) Division. Subcontractors provide prime contractors with data. The prime contractor integrates these data with his own and sends them to the data exchange center in a format ready for input to the computer. New data and updates will be entered in the data bank on a continuous basis--not just at design milestones. The data bank contains human factors data from several aerospace systems. This makes it possible for a System Program Office (SPO), or SPO-designated users, to compare data longitudinally within a system and across systems.

All of the techniques and programs available at the data exchange center are available to contractors for use on their own computer equipment. If certain special techniques such as large-scale simulation cannot be conducted at the local center, the services of the data exchange center may be requested through the appropriate SPO.

Two modes of communication with the data exchange center are used. SPO's and user commands have direct communication with the data bank by means of teletypes operating in a time-shared mode. Requests, short responses to requests, and current awareness notifications can be sent economically over teletype lines. Postal services are used to deliver large volume printouts. Other users will use postal services or teletype to the SPO control group for all input and output communications.

The central processing unit (see figure 3) must be a medium to large computer with features adaptable to time-shared multiprocessing and multiprogramming operations. It must have an extremely flexible growth potential for increased processing power and storage capability.

The input/output (I/O) processor, shown separately, controls all data transfers. It allows the central processor to be free to continue basic processing while various priorities of data transfers are handled separately. Among these priorities are teleprocessing traffic, memory transfers, and peripheral buffering.

The data bank memory consists of a variety of storage capabilities, ranging from direct random-access to off-line cards and tapes. Because of the volume and growth rate of the data bank, additions to storage are required from time to time. Microfilm storage supplements the data bank. An index to the microfilm is maintained in the data bank. Thus, as data are retrieved from the computer storage, references are listed for supplemental retrieval from microfilm.

Teleprocessing capability is described here as a direct hookup of remote and on-line teletype stations with the I/O central processor. These stations may be in the computer room, SPO's in the same building, or across the country. A combination of hardware and software safeguards protects proprietary and classified information.

The SPO control group assists and monitors the data cycle within the exchange facility. This group would be an extension of each of the SPO's involved. The group would hopefully stimulate cross-talk between the SPO's and provide

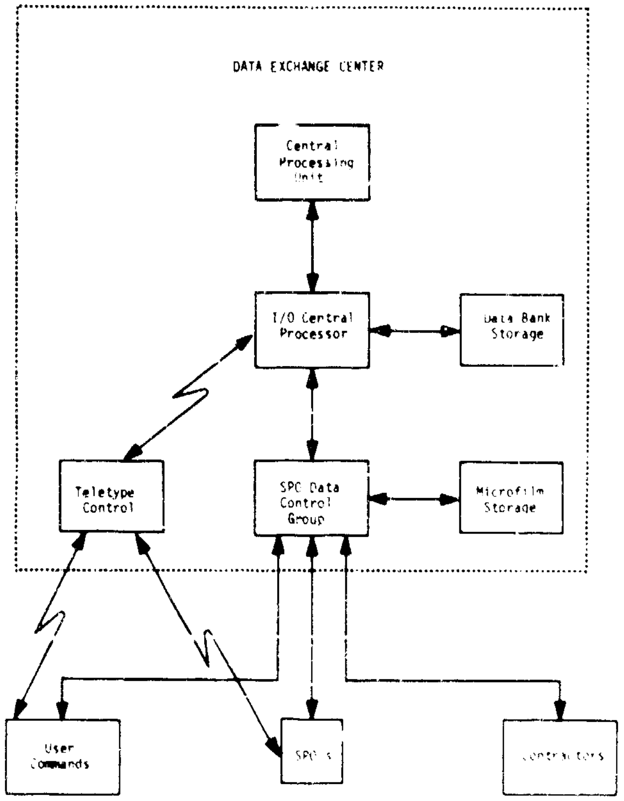


Figure 3. Operation of Data Exchange Center

an added measure of control on proprietary information. They are responsible for the collection, review, and verification of incoming data. They also maintain the software; handle the reproduction of materials including data lists, charts, and reports; and monitor the releasability of all outputs.

Define Pilot Study Requirements

Pilot study requirements were developed to focus more clearly on the operational aspects of computer software functions. A concept of the computer software functions was developed to exemplify the inner working of an operational system and to narrow down the identification of research areas discussed next.

Select Research Areas

Five areas, considered fundamental from the standpoint of studying the problem and proposing solutions, were identified. These five areas are presented and discussed below:

- Analysis of Human Factors Task Data, Data Relationships, and Classification Schemes

One of the most important considerations in applying information system techniques to data handling problems is the determination of the characteristics of the data to be handled by the system. The factors involved in gaining a complete understanding of the data include their diversity, application, environment, content, life cycle, and significant phases in their generation and use. The personnel involved in data handling are also important factors--their problems, response times, tools, scheduling and products. Therefore, an analysis of the data and of the people directly concerned with the data is needed.

- Vocabulary and Thesaurus Techniques Applied to Human Factors Task Data

A capability that increases the effectiveness of communication among man/machine/software functions is highly desirable in computer systems. Vocabularies in today's systems cannot be used as off-the-shelf components--they must be tailored to the environment of the system. In this research program, a special consideration--standardization--is apparent in studying task data terminology. Not only is the problem apparent for treating multisystem data, but also in providing for multiusers. A data vocabulary is essential to this information system and requires careful study in its application.

- Computer Storing and Retrieval of Human Factors Task Data

Particular problems, identified in the preliminary research program (Hannah et al., 1965), that directly concern users of task data are the handling of large amounts of data, dealing with scattered sources, and drawing from previous and current experience with systems. The recommendations resulting from the preliminary research call for a store of information, mutually available to those who require such information, in a form that expedites the use of that information. The recommendations led to the conclusion that a factual storage and retrieval capability is needed which always keeps data up-to-date.

- Analytical and Simulation Modeling Techniques Applied to Human Factors Task Data

Techniques employed by analysts in refining task data into useful products are often the result of scientific analysis and modeling procedures. Such procedures are highly amenable to computer applications. If raw quantitative data are easily accessible in a computer store, various processing techniques can be immediately and directly applied to refine the data into the required products.

- Current Awareness Techniques Applied to Human Factors Task Data

A special problem pointed out by Hannah et al.(1965) concerns the inability of analysts to keep up with the fast pace of data generation. This is particularly true when the data are scattered, or if channels providing awareness are inefficient. Inefficiency is almost always present when several separate organizations are involved. The requirement that specialists be immediately aware of the generation of data, when they are pertinent to their interests, can be facilitated by the functioning of a common data store. The problem of assuring awareness can be lessened by setting up a major automated control point that acts as a disseminator and provides notification of pertinent data to interested people. The operational system can act as the control point.

Conduct Research

The activity during this stage led to the formulation of an initial, yet detailed, design. This activity included describing particular problems and objectives for each research area, as well as planning and carrying out the research. Figure 4 shows the interface relationships of the five research areas. The results provided the basis for the development of the pilot study design specifications. The nature of the operational system concept and its man/machine functions became clearer as problems were explored. Modifications to the concept were made during the course of the study, as shown by the feedback loops in figure 1. The results of the research in each of the five areas are reported in Potter et al. (1966) and in Sections III through VII of this report.

Develop Pilot Study Design Specifications

The pilot study design specifications were generated in response to the research results drawn from the five research areas discussed previously. The specifications describe and identify the requirements, techniques, functional interface, and approach necessary for the development of a data handling system. Since the objective of the research was not to develop a full operating system, but rather to explore techniques necessary for such a system, the specifications also identify those areas which are carried into computer software and those which will be tested manually or given narrative treatment. These specifications included such topics as: detailed characteristics of the data used as inputs, necessary software required for input, retrieval, update and output, thesaurus, analysis and simulation, user's and controller's guides, and the environment necessary to support the development of the data system. The design specifications provided both a direction for research and an approach to be used in the development of an experimental data system.

The specifications are reported in:

Tulley, A. T. and Meyer, G. R. Implementation of Computer Software Techniques to Human Factors Task Data Handling Problems. AMRL-TR-67-127 (AD 663 209).

Pilot Study Experimental System

The Pilot Study Experimental System (PSES) encompasses all research areas that are carried to test and evaluation and will ultimately result in recommendations for the development of an operational data handling system. The PSES development was divided into four distinct efforts: (1) Identify Pilot Study Experimental System Design, (2) Develop Pilot Study Experimental System, (3) Conduct Tests, and (4) Evaluate Test Results and Prepare Recommendations.

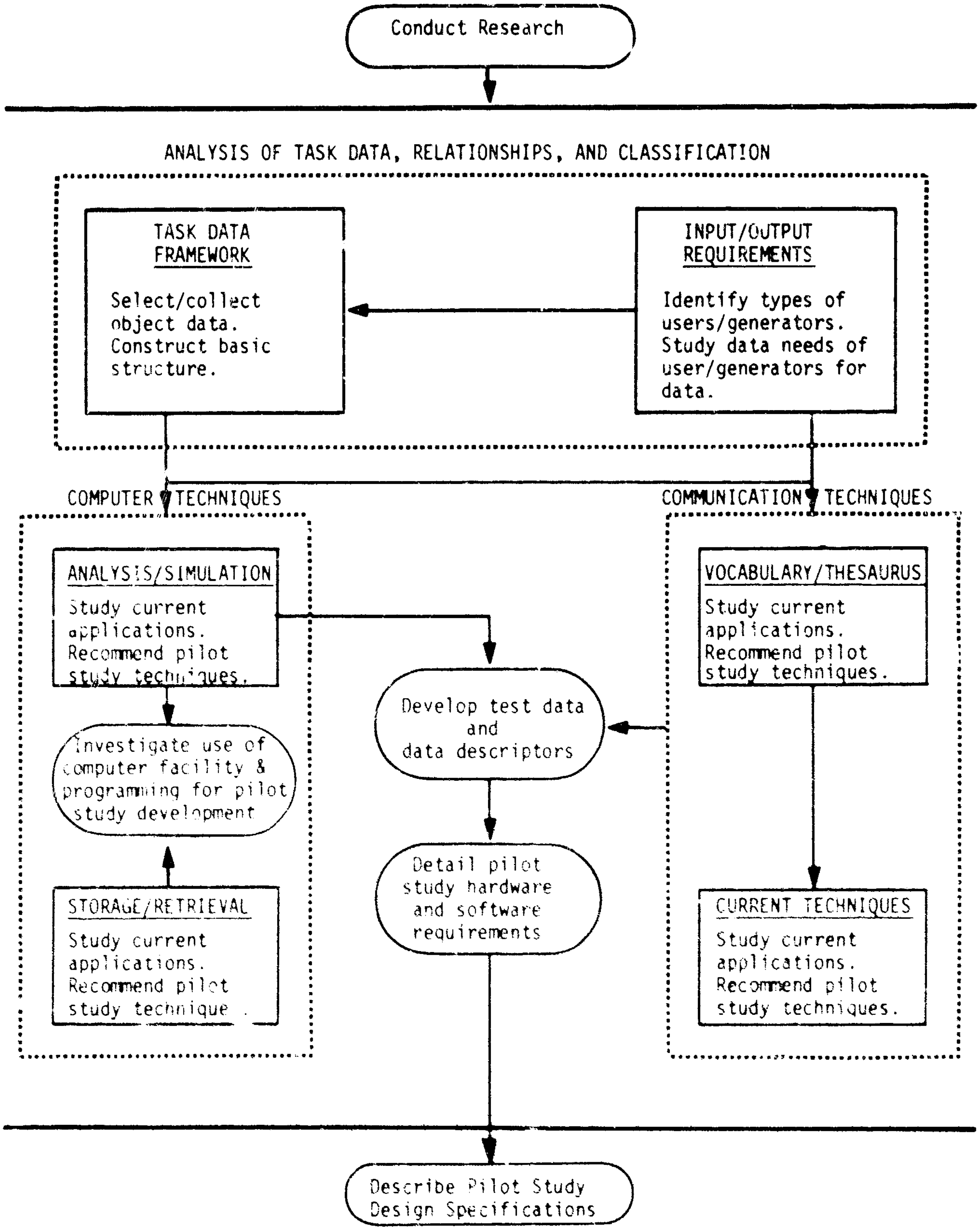


Figure 4. Interface of Research Areas

Identify Pilot Study Experimental System Design

The design specifications of an experimental system satisfy those areas of the pilot study that are carried into the development of a computerized evaluative system for handling human factors task data. The specifications, reported in Tulley and Meyer (1967), resulted in the development of the PSES. The PSES provided the means by which data handling techniques were tested and evaluated.

Develop Pilot Study Experimental System

The PSES was developed to focus more clearly on all aspects--hardware, software, personnel, environment, etc.--of a total operating data system. While the PSES was not regarded as an operational system for field use, it did provide a means for determining the feasibility of such a system. The processes and steps that led to the development of the PSES are discussed in Sections II and III of this report. The development procedures included: (1) the generation of an experimental data pool, (2) the application of computer techniques, (3) interim development tests, and (4) implementation of modifications to the PSES in accordance with test results.

The design of any information system is based upon its functions, that is, what it is intended to do. The system requirements (see page 4) specify the conditions for handling task data in a computerized system. Included in the requirements are stipulations that affect the manner in which the conditions are met, such as user orientation, selectivity in retrieval, vocabulary standardization. To the extent possible, these conditions were applied to the development of the PSES. State-of-the-art considerations were determining factors with regard to the application of computer hardware and software to the PSES functions. Manual operations were applied where automation was impossible or impractical. For example, vocabulary control was achieved by manual application of thesaurus technology. Though nonautomated, the thesaurus itself is part of the total PSES operation, and is reported in:

Oller, R. G. Human Factors Data Thesaurus (An Application to Task Data), AMRL-TR-67-211 (AD 670 578).

User-orientation was a prime consideration in the selection of computer hardware and software. This means that the user must be able to communicate directly with the computer without programmer intervention. The user must also be able to access data selectively within a variety of levels of specificity and obtain a rapid response to queries. The computer hardware and software applications to the PSES are discussed in Section III of this report.

Conduct Tests

When a relatively firm concept of the system had been achieved and a set of procedures developed, the PSES was subjected to realistic test situations. The purpose of the test was to obtain data for evaluating the techniques developed during the research period, whether manual or automated. The test situation involved the use of the computer stored experimental data pool, programs, and on-line computer hardware to run "live" queries. Human factors specialists engaged in system development projects participated in the test program. With the assistance of a user's guide, specially designed for the test program, the specialists accessed data from computer storage. Questionnaires and debriefing periods were used to obtain data for evaluating the PSES functions. Included in the questionnaire were questions regarding the effectiveness of the training period, the use of the guide, difficulties encountered in the retrieval process, types of data that should be added to the experimental data pool, possible uses of the data system, and the applicability of the system concept to aerospace system development programs. The debriefings were directed primarily to clarification of questionnaire responses.

Evaluate Test Results and Prepare Recommendations

Test results were evaluated for possible immediate changes or recommended changes to the PSES design. The test results also served to identify those areas needing further research, as shown by the feedback loops in figure 1. Changes and recommendation for changes are discussed in the appropriate sections of this report. The test procedures and evaluation of the results are presented in:

Reed, L. E.; Reardon, S. E.; and Tulley, A. T. Test and Evaluation of Computer Techniques for Handling Human Factors Task Data (in publication).

Instructions for the operation and maintenance of the PSES functions were prepared in user's and controller's guides. These instructions are reported in:

Reardon, S. E. Computerized Human Factors Task Data Handling Techniques: User's and Controller's Operating Guides, AMRL-TR-67-226 (AD 671 531).

REPORT ORGANIZATION

- Section II is concerned with the research into human factors task data analysis, development of computer data classes and files, and the preparation of data for input to computer storage.

- Section III contains a description of computer software for the PSES environment and the preparation and uses of guides.

- Section IV discusses the development of current awareness notification techniques, use and construction of user profiles, and a description of the programs developed to accomplish this function.

- Section V discusses techniques for standardizing vocabulary, development of a system-related thesaurus, and applications of a standardized vocabulary to the experimental data pool contents.

- Section VI contains a discussion of the reliance and application of classification techniques to human factors task data problems, faceted classification technique development, and a report of a manual application of the technique to a subset of the experimental data pool.

- Section VII discusses the problems, reviews techniques, and presents probable application of analysis and simulation techniques to task data.

SECTION II

TASK DATA FILE DEVELOPMENT

INTRODUCTION

The Pilot Study Experimental System (PSES), discussed in Section I of this report, provides a means to test and evaluate data handling techniques. It also provides the primary tool for determining the applicability of classification schemes for organizing human factors task information into computer acceptable form, and for determining the adequacy of vocabulary controls that must be imposed on the data. Research that led to the development of data classification schemes for the PSES was reported by Potter et al. (1966). An advanced, but untried, classification scheme, is presented in Section VI of this report. The development of vocabulary controls was reported in Oller (1967) and in Section V of this report.

This section discusses the development of an experimental data pool for PSES test and evaluation exercises. Two subjects are discussed: (1) the selection and organization of sample task data for the PSES, and (2) the preparation of data for computer storage. The first subject covers the selection of aerospace systems, selection of data types, identification of classes of data, and selection of sample data for input to the PSES. Classification structures and vocabulary controls are discussed briefly in context with the total development of the experimental data pool for the PSES. The second subject includes all processes necessary for converting the selected sample data into a format acceptable to computer storage and processing.

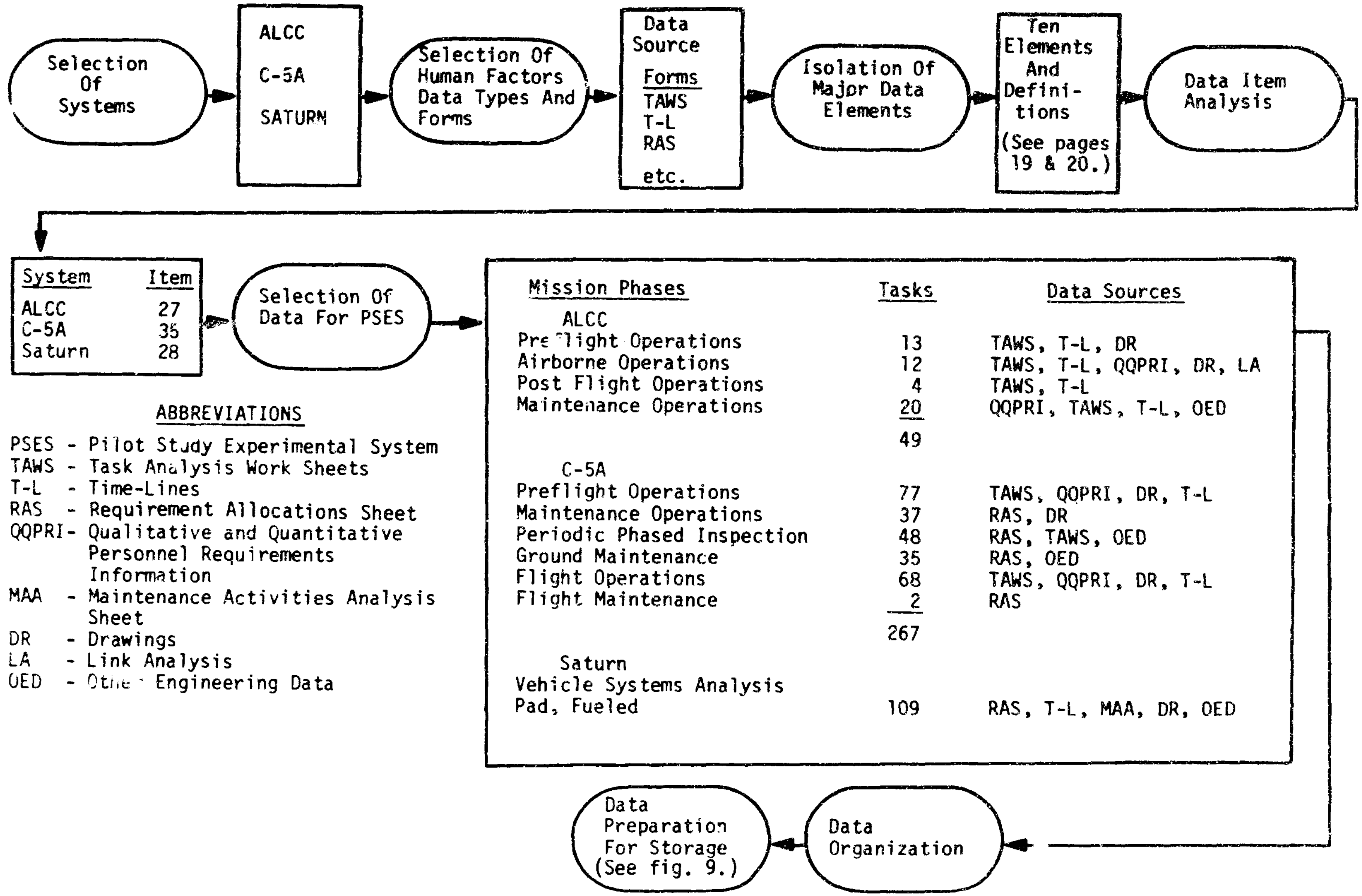
SELECTION AND ORGANIZATION OF DATA

Figure 5 illustrates the overall activities that led to the selection of a representative sample of data for input to the PSES. The activities begin with the selection of aerospace systems to be considered in the research and terminate with the selection and organization of data to be prepared for computer storage.

Selection of Systems

Data handling techniques cannot be developed and tested in a vacuum. To more realistically fulfill the requirements listed in the preceding section (see page 4), aerospace systems in early stages of design were selected for this study. The following criteria governed the selection of systems:

- The systems should be in early stages of development so that the evolutionary process of data generation and use can be considered.
- The systems must contain a personnel subsystem or life science program.
- The systems must contain development programs that require the generation of task information.



Mission Phases	Tasks	Data Sources
ALCC		
Preflight Operations	13	TAWS, T-L, DR
Airborne Operations	12	TAWS, T-L, QQPRI, DR, LA
Post Flight Operations	4	TAWS, T-L
Maintenance Operations	20	QQPRI, TAWS, T-L, OED
	49	
C-5A		
Preflight Operations	77	TAWS, QQPRI, DR, T-L
Maintenance Operations	37	RAS, DR
Periodic Phased Inspection	48	RAS, TAWS, OED
Ground Maintenance	35	RAS, OED
Flight Operations	68	TAWS, QQPRI, DR, T-L
Flight Maintenance	2	RAS
	267	
Saturn		
Vehicle Systems Analysis		
Pad, Fueled	109	RAS, T-L, MAA, DR, OED

ABBREVIATIONS

PSES - Pilot Study Experimental System
TAWS - Task Analysis Work Sheets
T-L - Time-Lines
RAS - Requirement Allocations Sheet
QQPRI - Qualitative and Quantitative Personnel Requirements Information
MAA - Maintenance Activities Analysis Sheet
DR - Drawings
LA - Link Analysis
OED - Other Engineering Data

Figure 5. Development of PSES Data Base Content

• The systems should be representative of those developed for the government, e.g., space systems, aircraft systems, missile systems.

To be effective, data handling techniques must be applicable to different types of aerospace systems. The research must determine whether or not a data system can be developed that processes information generated from totally different types of aerospace systems and still provide for accessing data across systems. Thus, rather than select a sample of similar types of systems, e.g., aircraft systems, or subtypes of similar systems, e.g., fighters or trainers, three different types were chosen:

Aircraft system-Heavy Transport Aircraft (C-5A)
Command and control system-Airborne Launch Control Center (ALCC)
Space booster system-Saturn V, Stage IC (SV-IC)

At the time of selection, all three systems were in various stages of early development, and all required some form of human factors effort in their development process.

Selection of Human Factors Data Forms

To be useful, a data system must be capable of processing information in all its various forms and at any level of detail. This requirement is particularly important to human factors information, since the forms of the data are as varied as the ways they are reported and used. The research problem was to select an aggregate of human factors data containing these characteristics. In their report of the preliminary research, Hannah and Reed (1965) concluded that human factors task data constitute a large body of information used throughout system development and that the use of this information is essential to the system development process. Task data are used in some way throughout every stage of system development, are often used repeatedly, e.g., the same data may be used to generate training requirements and manning estimates, and contribute to a large variety of aerospace system products. Figure 6 illustrates some of the various uses made of task and task analysis data in Air Force Personnel Subsystem (PS) programs. Furthermore, the forms that task data take, e.g., narrative, quantitative, and the formatting structure of these data, e.g., fixed formats, graphs, drawings, are representative of the total personnel subsystem data forms and formats used in aerospace system development programs.

The procedures and requirements for generating task information vary from system to system. Task information varies considerably in both content and form, depending on the system development program problems, the system being analyzed, the period in the system life cycle, and on the idiosyncrasies and needs of the data generator. The research problem was to select a group of task data from each of the three aerospace systems. The task data selected had to be representative of the total task data generated on each system and had to form a coherent group with regard to uses in the three aerospace systems. That is, the data may vary in form and content, but their uses, e.g., generation of personnel and training requirements, maintenance procedures, job analysis, must be similar. Appendix I contains illustrative sample for-

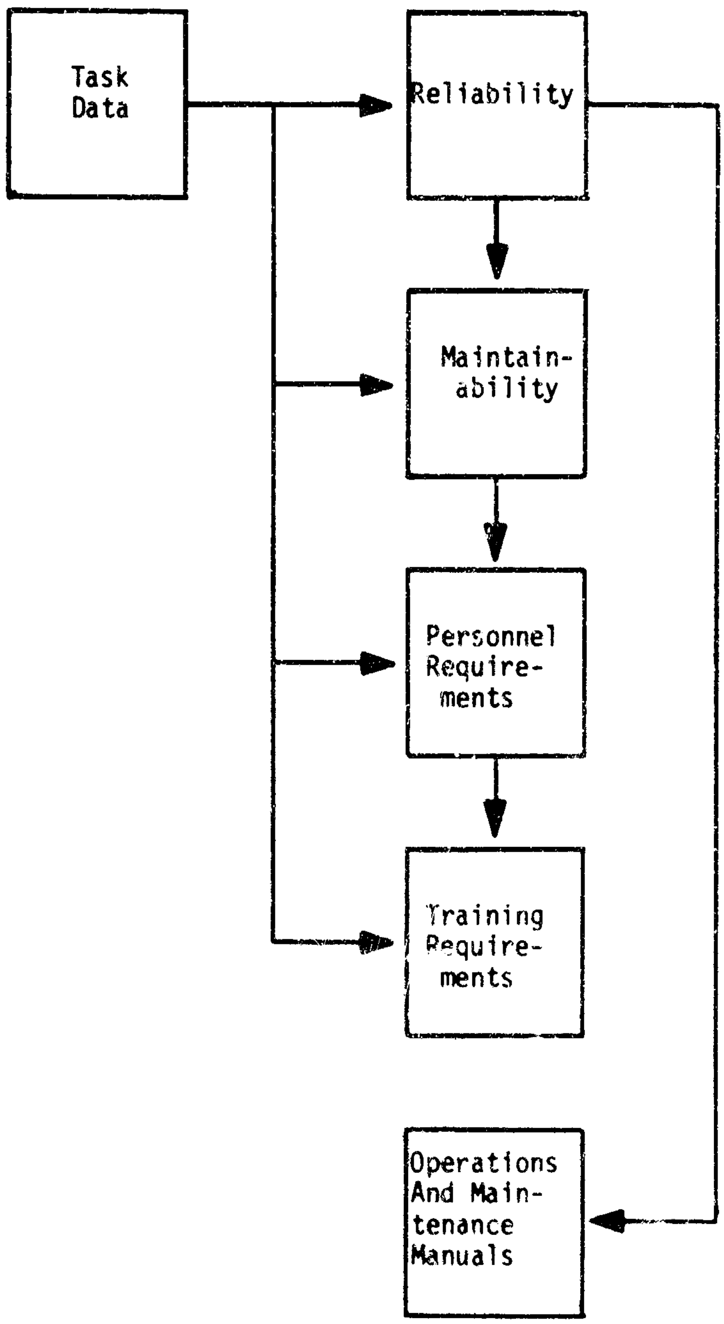


Figure 6. Uses of Task Data in System Development Programs

mats used by originating aerospace system contractors for recording task information on the ALCC and C-5A. These include formats, such as task analysis worksheets (TAWS), Requirements Allocation Sheets (RAS), time-line analysis (TL), engineering and other drawings (DR), task listings in Qualitative and Quantitative Personnel Requirements Information (QQPRI) documents, and other engineering data (OED). A large sample of these formats, containing operational and maintenance task information on the three systems, was analyzed for content and applicability to computer storage in accordance with the requirements listed on pages 4 through 6 of this report.

Isolation of Major Data Elements

An important consideration in applying information system techniques to data handling problems is the determination of the characteristics of the data to be handled by the system. Factors involved in gaining a complete understanding of the data include their diversity, application, environment, content, life cycle, and the significant phases in their generation and use. Since the data system must adhere to multiple user requirements, the research must determine if a data structure can be developed for diverse types of aerospace systems that must rely heavily on common storage and indexing techniques. The need for a common method of labeling and defining data is apparent if the automation goals of the research are to be met. Currently there are no precedents for a user-oriented information system that includes such a large assortment of data types generated in support of many system development programs that establishes information handling techniques on a factual rather than a document level.

The first need was to create an organizational framework that accommodates task data generated in support of different aerospace system development programs. To allow the user to access data across systems, information common to all systems, as well as system specific information, had to be identified, labeled, and defined. The procedure used, and reported by Potter et al.(1966), was based on the derivation of common data elements. A data element, in this context, is a label that represents a generic class of information containing any number of subordinate classes of data. The defined elements must accommodate a wide variety of data and must serve as the common pivotal point for conducting detailed content analysis of specific data items. Data generated in support of the three systems selected for this research were used to derive a list of data elements. The first step was accomplished by comparing the major information content of the data formats (see Appendix II). This exercise produced the following ten elements presented with their definitions

	Data Element	Definition
1.	Object System	The designator of a specific aerospace system.
2.	Mission Information	A specific operational maintenance profile or profile segment for the specified object system.
3.	System Information	Specific data relating to the hardware and software required to accomplish the specified mission or segment.

4.	Performance Description	Specific data relating to the level of detail to be included in the related performance descriptions
5.	Performance Characteristecs	Specific data relating to the man/machine, and man/man interfaces and duties required to accomplish the specified mission or segment
6.	Hardware Characteristics	Specific data regarding the human engineering characteristics of the hardware required to accomplish the specified mission or segment
7.	Personnel Description	The job title and/or Air Force specialty code of personnel required in the specified activity--special skills or knowledge required of the performer are also noted
8.	Time Information	Specific data regarding performance or mission related time values
9.	Remarks	Miscellaneous comments and remarks necessary to explain any material contained in other data elements
10.	Source Identifiers	Specific data regarding the origin and author, date of completion or revision, references used by the generators, and security or proprietary restrictions

Data Item Analysis

The ten major elements represent classes of data common across the C-5A, ALCC, and Saturn, and represent the most general level of information content for these there systems. The next step was to carry the content analysis to the data item level, e.g., particular statements of human performance, hardware, special skills, and knowledge. Thus, the approach was to first classify task data into a generic structure--elements--then provide for subclasses--data items--in accordance with the requirements for using data. This approach involved specifying the level of detail needed to access selectively individual data items according to user's needs. The primary objectives of the data item content analysis were as follow:

- Identification of Common Data Items
  To provide a standard frame-of-reference for retrieving data within and across aerospace systems, it is necessary to isolate those data items common to all systems. The ways in which data are referred to vary from system to system and from analyst to analyst. The same information may take the form of numbers, be described in narrative form, or be coded. For example, there is no standardized method for defining or describing personnel hazards involved in the performance of tasks. One analyst may place the degree of hazards involved in a particular task on a rating scale, while another analyst simply describes hazards in narrative form. In other instances, personnel hazard data may be embedded in other cate-

gories of information, such as task criticality, personnel safety, criticality to mission success, or actual accomplishment of tasks. By choosing a single term to refer to hazard information, the likelihood of data loss in the retrieval process is reduced. In this way, the data user is able to retrieve hazard information across aerospace systems. Where differences in data form exist, e.g., narrative descriptions vs. ratings, computer based comparisons of these data cannot be made, e.g., retrieve tasks, across systems, with the highest hazard rating. This would require standardized techniques for generating and analyzing data in aerospace system development programs. For the PSES, the user retrieves the data and performs the desired comparisons manually.

- Data Item Definitions
  Each data item is defined in accordance with content and usage. Coded data are defined and aerospace system names or codes are identified in each definition for quick manual reference during retrieval.

- Selection of Data Item Labels
  Upon completion of the data content analysis, standard labels for common data across systems are selected. For example, data pertaining to hazards for all systems are labeled HAZARDS, even though the form of data may be different for each system. Data that are unique to a system are also labeled.

- Data Item Categorization
  A categorization scheme appropriate to each data item is selected and classes of related data items are grouped into the appropriate data element. The categorization scheme selected is determined by the data item characteristics and content. A variety of categorization schemes may be required to best organize the data. For example, certain data are amenable to hierarchical arrangements, while others are best arranged in alphabetical order or by key terms.

- Identification of Data Item Characteristics
  The characteristics of the information contained in each data item are defined. The characters, e.g., alpha, numeric, symbolic, or combinations of these; and make-up, e.g., number of numeric digits, maximum number of alpha characters, number of lines of narrative, for each data item are identified.

The data item analysis, reported in detail by Potter et al.(1966), generated 27 ALCC data items, 35 C-5A data items, and 28 Saturn data items as listed in Table I. Results of the data content analyses for the three aerospace systems are presented in Appendix II, along with statements about the data sources. Data item (computer element) definitions are presented in Appendix III.

Selection of Data for the PSES

The total amount of human factors task data generated on any one aerospace system development program is unquestionably large and unwieldy. The three

TABLE I. Data Items for ALCC, C-5A and SATURN

ALCC		C-5A		SATURN	
1	(ENTRY NUMBER)	1	(ENTRY NUMBER)	1	(ENTRY NUMBER)
2	(ENTRY TYPE)	2	(ENTRY TYPE)	2	(ENTRY TYPE)
3	(ENTRY DATE)	3	(ENTRY DATE)	3	(ENTRY DATE)
4	(SOURCE IDENTIFICATION)	4	(SOURCE IDENTIFICATION)	4	(SOURCE IDENTIFICATION)
5	REVISION	5	REVISION	5	REVISION
6	(REVISION DATE)	6	(REVISION DATE)	6	(REVISION DATE)
7	REMARKS	7	REMARKS	7	REMARKS
8	(MISSION PHASE)	8	(MISSION PHASE)	8	(MISSION PHASE)
9	(MISSION SEGMENT)	9	(MISSION SEGMENT)	9	(MISSION SEGMENT)
10	FUNCTION	10	FUNCTION	10	FUNCTION
11	TASK	11	TASK	11	TASK
12	(PERFORMANCE DESCRIPTORS)	12	(PERFORMANCE DESCRIPTORS)	12	(PERFORMANCE DESCRIPTORS)
13	LOCATION	13	LOCATION	13	LOCATION
14	(HARDWARE INFORMATION)	14	(HARDWARE INFORMATION)	14	(HARDWARE INFORMATION)
15	(SPECIAL TOOLS/EQUIPMENT	15	(SPECIAL TOOLS/EQUIPMENT)	15	(SPECIAL TOOLS/EQUIPMENT)
16	(TASK FREQUENCY)	16	(TASK FREQUENCY)	16	(TASK FREQUENCY)
17	HAZARDS	17	HAZARDS	17	HAZARDS
18	(SAFETY PRECAUTIONS)	18	(SAFETY PRECAUTIONS)	18	(SAFETY PRECAUTIONS)
19	(PERFORMANCE TYPE)	19	(PERFORMANCE TYPE)	19	(PERFORMANCE TYPE)
20	(TOTAL TASK TIME)	20	(TOTAL TASK TIME)	20	(TOTAL TASK TIME)
21	(PERSONNEL NAME)	21	(PERSONNEL NAME)	21	(PERSONNEL NAME)
22	AFSC	22	AFSC	22	*(PERSONNEL CODE)
23	(PERSONNEL NUMBER)	23	(PERSONNEL NUMBER)	23	(PERSONNEL NUMBER)
24	(PERSONNEL TIME)	24	(PERSONNEL TIME)	24	*CRITICALITY
25	DIFFICULTY	25	(PERFORMANCE DIFFICULTY)	25	*(FUNCTION DESCRIPTORS)
26	CRITICALITY	26	(PERFORMANCE CRITICALITY)	26	*(FUNCTION START TIME)
27	(TRAINING REQUIREMENTS)	27	(TRAINING REQUIREMENTS)	27	*(FUNCTION CHECKOUT TIME)
		28	*(PERFORMANCE FREQUENCY)	28	*(FUNCTION TIME BUDGET)
		29	*(EQUIPMENT VISIBILITY)		
		30	*(EQUIPMENT READABILITY)		
		31	*(EQUIPMENT REACHABILITY)		
		32	*(EQUIPMENT MANIFULABILITY)		
		33	*(SPECIAL SKILLS)		
		34	*(START TIME)		
		35	*(STOP TIME)		

* System Unique Data Items

systems selected for this research are no exception. To facilitate the research process, the experimental data pool for the PSES was kept modest in size. Technically, nothing is gained by continuously loading an experimental data pool. However, data for PSES experimentation were representative of the total task data generated for systems in the early acquisition phase. The central block in figure 5 shows the mission phases for each system, the number of tasks selected for each mission phase, and the sources from which data were obtained.

The data selected from ALCC included operational and flight maintenance task information. Although the ALCC is a subsystem to a larger system, task data concerned with the interface with the larger system were included when necessary to specify ALCC tasks. The maintenance data selected were limited to in-flight and flight line maintenance; no field, or depot level maintenance data were included.

Sample operational and maintenance task data were selected from C-5A documents. The operational data consisted of tasks performed by the flight crew on a complete mission--preflight through postflight. Maintenance data consisted of turnaround and periodic tasks, and of a selection of field and organizational level maintenance tasks, including component level detail required to diagnose and correct faulty subsystems. No depot level maintenance tasks were included.

The Saturn data consisted entirely of maintenance operations, including repair, remove and replace tasks to the individual part level for sequential operations. Sequential operation consisted of maintenance loops for the Saturn Launch Vehicle Countdown.

Data Organization

The organization of data for storage is fundamental to the development of any computer technique for handling task information. The data organization must be responsive to the retrieval needs of users (see Section I, page 2).

Potter et al.(1966) indicated that in some data systems simple organizational schemes are adequate. For example, bibliographic data are often organized by subject or title; associated data, such as publication author, and keywords are all linked or grouped with primary reference points, e.g., subject. Searches are made using the subject as the prime search key and associated data are thus retrieved with reference to this primary key. More complex organizational schemes are needed when the requirements to retrieve involve a higher level of selectivity. A greater degree of depth is needed if many subassociations are implied in the data, e.g., handling task data on a factual level. The data can be subdivided into many hierarchical levels of detail, which together form a condition for data retrieval. For example, a task statement (a particular level of detail) may be divided in the verb and noun, and each task may be further divided into several categories, such as time, position, equipment and criticality. The computer software techniques for handling data in hierarchical arrangements are discussed in Section III, page 33.

A second problem in the development of a fact retrieval system is the selection of a particular data item under which all other data may be organized (a computer entry). Implicit in the selection of a data item is the level of detail necessary for selective retrieval. The data item selected for the PSES experimental data pool was the task--statements that describe human actions in aerospace system operations and maintenance. All other information either identifies the task, e.g., the system, the mission phase under which the task is performed, entry dates; or describes the task in terms of associated data, e.g., time to perform, hardware required, task criticality. For the experimental data pool, items 1 through 10 in Table I identify the ALCC, C-5A, and Saturn data and items 12 through 35 describe the task.

The data values (information content) that identify and describe a task are grouped as one entry to the experimental data pool, as illustrated in figure 7. Each of the items (categories) represented by the blocks in the figure contains one or more data values that identify and describe a single task. Figure 8 shows how entries are grouped for the computer data base (the group of data elements under which data values are organized for computer storage). For the experimental data pool, the data items shown in Table I are identical to the computer data elements that form the data base (see Section III). Typical data values for some of the data are shown in figure 8. Note that the hierarchical arrangement of the data is maintained through repetition of data values. Thus, more than one task appears under a single mission phase and mission segment to allow the user to access data at either level of detail. The data values that describe the task are unique to each task.

Ideally, the need for accessing data across all aerospace system (see item 9, page 5) should result in the development of a single data base. This would provide the user with a capability to retrieve information from one or any number of aerospace systems with a single computer query. The creation of a single data base might have been accomplished by adding a data item called SYSTEM to the data base elements. This item would have then served as a condition for retrieval. Data items unique to particular systems would have been coded to designate them as empty cells on entries for other systems. However, the need for protecting data having security classification and/or proprietary status (see item 11, page 5) requires that the integrity of each aerospace system data base be maintained. Access to the data system must be rigidly controlled to enforce the provisions of security and to protect proprietary information. To satisfy this requirement, three separate data bases, one for each aerospace system, were created for the PSES. Access to each is through the aerospace system name, e.g., ALCC. The technique for selectively accessing data from each of the three data base contents is identical.

The creation of a separate data base for each of the three aerospace systems prevents access of information across systems in a single query. Since the organization of data is identical for each, qualified users can retrieve data across systems by accessing each data base separately and repeating the same query statement on each. That the user must query each data base separately to access data across aerospace systems does not present an appreciable problem, but the process is inconvenient and time consuming. To aid the user, a fourth data base was created, called INDEX. This data base contains reference points to data contained in the three aerospace system data bases. The computer elements are similar to the system data bases, but only unique values for the ALCC, C-5A, and Saturn are stored. Thus, while a particular AFSC

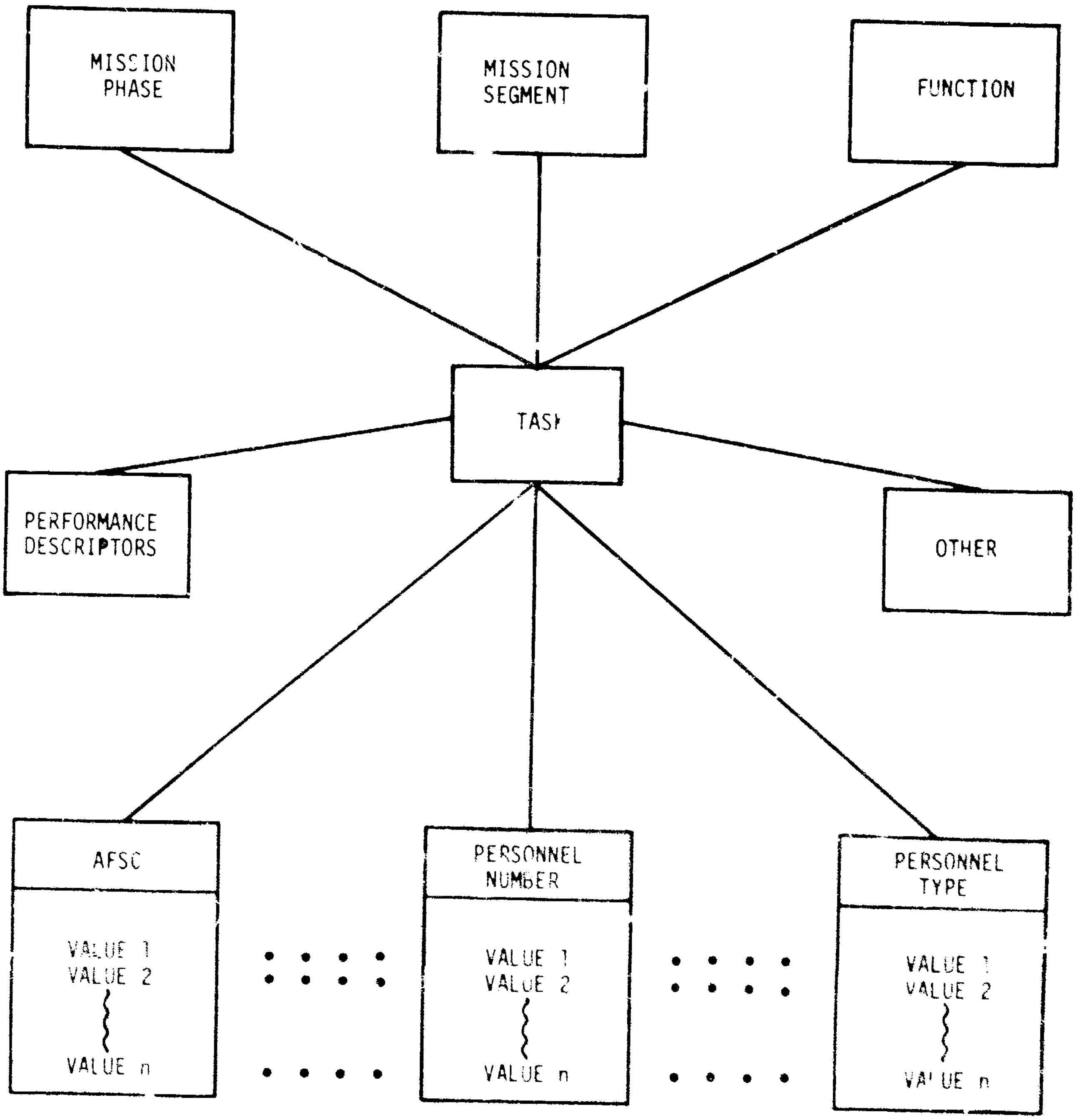


Figure 7. Data Base Entry

DATA BASE ENTRIES	DATA CATEGORIES			
	MISSION PHASE	MISSION SEGMENT	TASK	TOTAL TASK TIME
1	PREFLIGHT	ACTIVATE ENGINES	DISCONNECT GROUND POWER	.06
2	PREFLIGHT	TAXI	RELEASE BRAKES	.06
3	FLIGHT	TAKE-OFF	RETRACT LANDING GEAR	1.00
4	FLIGHT	TAKE-OFF	RETRACT FLAPS	1.50

Figure 8. Data Base Groupings

code m y appear numerous times in the ALCC data base (depending on the number of tasks assigned to that AFSC), INDEX contains only one reference point to that AFSC. This technique permits the user to determine, in one query, if the particular AFSC in question has also been assigned to other systems. For the PSES experimental data pool, a selected number of data items was used for the INDEX data base. The data items are shown in Appendix V.

DATA PREPARATION FOR COMPUTER STORAGE

Figure 9 illustrates the overall activities that led to the preparation of task data for storage in the PSES. The activities start with the development of a standard input form and conclude with the storage of data on magnetic tape and disc, as preliminary steps to computer processing of the data.

Input Form

As described previously, task information generated in support of the three systems exists in a wide variety of physical formats. They range from free formatted analysis worksheets and drawings to highly formatted forms (see Appendix I). To assist in the extraction and organization of data, a common format was required to record the data. A review of the data formats of the Air Force, NASA, and various contractors was conducted to determine whether an existing format could be used as a standard for the research. The formats examined did not provide the flexibility necessary for recording data from the three systems. Thus, a standard input form, based on the ten data elements on page 19, was designed (see Appendix IV). This standard input form served to compact the data from various locations in the generator's system support formats into a central location, facilitated the conversion of data into standard units, e.g., time into minutes and hundredths of minutes, and reduced the time required to convert the data into computer acceptable form--keypunching. The information recorded on each form was based on the data items shown in Appendix V.

The process of extracting information from original formats was regarded as a clerical operation, in contrast to the generation of data. Undergraduate university students assisted in this operation. An informal training program was prepared to acquaint the students with: (1) the content and use of human factors task information with which they were to work, (2) instructions for using the standard input form, and (3) the guidelines for extracting information from system formats. The data extraction guidelines for the three systems are in Appendix VI.

Quality Control

After data were transferred to the standard input form, these forms were examined for correctness. Spelling, abbreviations, and grammatical correctness were verified. If certain items of data were missing from the input forms, they were checked against the original data source to determine if particular items of data were indeed unavailable. Terminology was standardized as much as possible, particularly in the area of hardware information. For example, the same hardware may have been designated "copilot instrument panel", "copilot's instrument panel", and "CP instrument panel". All representations of time were converted into minutes and hundredths of minutes.

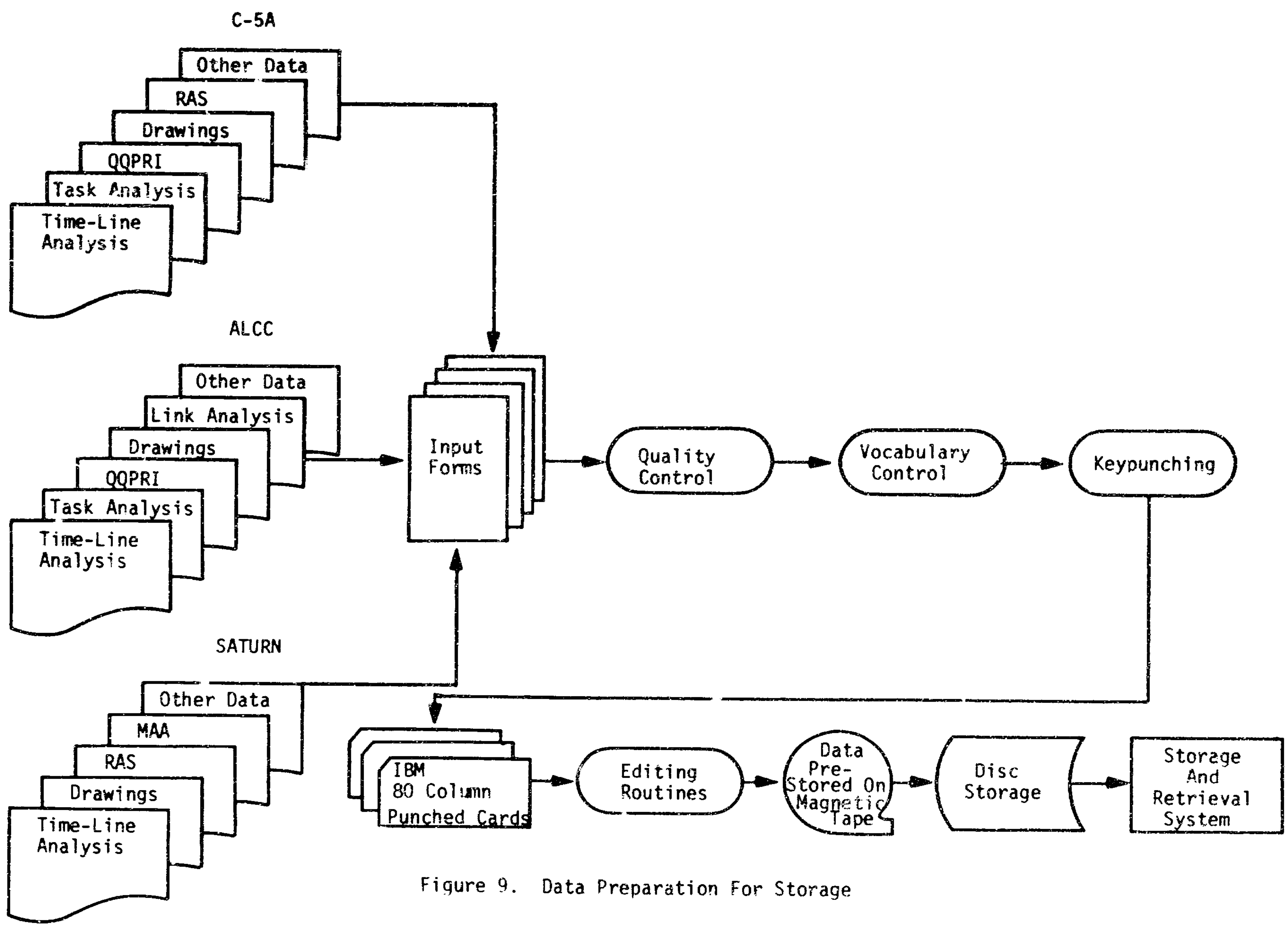


Figure 9. Data Preparation For Storage

Vocabulary Control

The final step before keypunching the data was to determine if the descriptors in the task statements adhered to the definitions in the controlled vocabulary and the rules governing word usage described by Oller (1967). The rules and standardized definitions helped to minimize the inconsistencies in meaning of all terms, control the proliferation of synonyms, reduce the loss of data in the retrieval process, and avoid the inclusion of jargon in the data base.

Keypunching

After all corrections were made to the input forms, their contents were transferred to standard 80-column IBM cards to be loaded into LUCID, the information storage and retrieval system used for PSES (see Section III). General formatting rules for data to be loaded into a LUCID data base are presented in Appendix VII.

Editing Routines

The single field number and value method of keypunching (see Appendix VII, page 141) was used for the PSES data bases and several short computer programs were written to aid in the edition of the data. These programs made a check for matching parentheses, missing field numbers and missing entry terminators.

Cards to Magnetic Tape

After all preliminary editing of the data, the cards were prestored on magnetic tape. This task was performed on an IBM 1401 computer where the data were stored at a density of 556 bits per inch. (This density is required for use by the IBM AN/FS Q-32 computer, on which LUCID operates.) The prestored tape was printed for use in further editing and then sent to the Q-32 computer room at the System Development Corporation facility at Santa Monica, California.

Disc Storage

In the Q-32, the data on the prestored tape were transferred to disc storage by the use of an on-line editing program. Further edition, where required, was then performed. At that time, the data were ready to be used by LUCID (see Section III).

REORGANIZATION OF THE DATA POOL FOR TDMS

System Development Corporation is developing the Time-Shared Data Management System (TDMS) to operate on the IBM 360 computer (see Section III). Partly due to recommendations made by Potter et al. (1966) for using TDMS as a further extension of the research on data handling, and partly as a result of the PSES tests, the data pool was reorganized into a structure that took advantage of the increased retrieval capabilities offered by TDMS.

Data Organization

Other changes were made as a result of limitations discovered in the organization of the PSES data pool. Use was made of the hierarchical structuring capability of TDMS. This capability enables the user to qualify and retrieve data at a finer level of detail. To accomplish this, the computer data element previously known as the TASK was eliminated entirely. The name TASK was retained as the heading of a group of elements that describe the man/machine action identified in the TASK STATEMENT. All tasks performed within specified segments of time were grouped in one entry and were identified by the mission phase, mission segment, and time segment in which they occur. Appendix VIII contains the changed or revised organization and Appendix IX contains the definitions of the revised data elements.

Data Preparation

Only C-5A data were reorganized for TDMS to illustrate the manner in which reorganization could be conducted. The data were transferred from the original input forms to a modified input form. Additional reference was made to the original data sources whenever questions arose about such items as the beginning and ending times of each task. After all data were transferred to the new forms, they were keypunched, with minor exceptions, in accordance with the rules presented in Appendix VII. The cards were then prestored on magnetic tape which were then ready for processing by TDMS.

SECTION III

APPLICATION OF COMPUTER SOFTWARE TECHNIQUES TO STORAGE AND RETRIEVAL

INTRODUCTION

Research into the application of computerized techniques to the processing of human factors task data (Potter et al., 1966) led to the establishment of a number of requirements for a data handling system (see Section I, pages 4 and 5) and to the conceptualization of such a system. The proposed experimental system was not required to possess all of the characteristics of the envisioned operational system, but was required to be similar enough in operation and capability in the major processing area to permit meaningful evaluation of the techniques used.

The heart of such an experimental system is the information storage and retrieval processing necessary to organize and maintain data within computer storage and to retrieve the data in accordance with the requirements. Because of the research characteristics of the PSES, it was not practical to develop or use highly specialized information storage and retrieval techniques that could not respond to changes in requirements as research progressed. Consequently, existing, general purpose data handling techniques were recommended to provide the information storage and retrieval capability for the PSES. Two specific generalized systems were recommended. The first of these systems is LUCID (Language Used to Communicate Information System Design) (Robert E. Bleier, System Development Corporation, TM-2624/100/00). The second and more advanced system is TDMS (Time-Shared Data Management System) which is currently under development (Vorhaus and Wills, 1967).

The LUCID system is described in detail in related research documentation (Tulley and Meyer, 1967). Briefly, LUCID is a generalized data management system developed by System Development Corporation (SDC) under the sponsorship of the Advanced Research Projects Agency (ARPA). It operates within the time-shared environment of a large-scale digital computer, the IBM/AN/FSQ-32, located at the SDC facility in Santa Monica, California.

Many elements of LUCID are being refined and expanded into TDMS, also under development by SDC. Though TDMS is being initially designed for the Model 65 IBM S/360 computer, the system can be adapted to increasingly sophisticated versions.

Both LUCID and TDMS provide an off-the-shelf computerized capability for application to problems that are not necessarily related but that share common processing requirements. The requirements center about the need to organize, maintain, retrieve, and present large volumes of data. Use of either system does not require knowledge of computer or programming techniques, and permits the development of a data handling capability in a minimum of time and training. This is accomplished without the cost of designing, developing, implementing, and maintaining a special-purpose system.

APPLICATION OF LUCID AND TDMS

The application of LUCID and TDMS to the handling of human factors task data within the frameworks of PSES is viewed from the standpoint of the overall requirements of the operational data handling system described by Potter et al.(1966). Of the requirements defined in Section I, pages 4 and 5, those that relate directly to information storage and retrieval require that the system:

- Provide for the storage, updating, and retrieval of human factors task data
- Accept and output data in a form approaching user-terminology
- Provide a user-oriented query language
- Provide a data bank structure flexible enough to allow for future expansion and inclusion of additional data elements
- Provide a data bank capable of frequent updating
- Be capable of retrieving similar information generated in support of different aerospace systems
- Be capable of selectively retrieving data elements by qualifying them with other data elements
- Provide the user freedom in specifying the format of outputs

Each of these requirements is considered in the discussion that follows.

Storage and Retrieval

The successful application of either LUCID or TDMS to the storage and retrieval functions of PSES depends upon adequately defined and organized information to be processed. Information selected for PSES consists of a pool of operational and maintenance task data generated in support of the ALCC, C-5A, and Saturn development programs. The general information content of the data pool is described in the previous section of this report.

Once the data have been defined and an organization established, the information must be input to the LUCID or TDMS system. This is accomplished for both LUCID and TDMS by informing the system of the uniquely identifiable data elements that are to be contained in the data pool, the name to be assigned to each, the type of information to be contained in each, and the relationships between elements. Once this has been accomplished, the functions of storing, updating, and retrieving information from the experimental data pool may be carried out. Complete indexing of data for efficient retrieval is assured.

Typical data elements established for LUCID identify: at what point in a mission a task occurs, who performs the task, the length of the task, and the equipment used. Establishment of elements is essentially accomplished by determining the key task information for the three systems. Although each of the systems contains similar overall categories of information (see Appendix II and the element list, pages 19 & 20), the uniquely identifiable elements needed to permit satisfactory computer manipulation of the data are not standard across the three systems. They vary in accordance with the information content of each system and the level of data available for entry into the experimental data pool. For this reason and to protect proprietary interests by preserving file integrity, three separate data bases were established within the experimental data pool--one for each system.

LUCID permits the user to move from data base to data base with ease and allows the user to apply the same retrieval techniques to each. Appendix V contains a list of the data elements used to describe each of the three systems. Appendix III contains an alphabetized list of elements and their definitions.

Only data from the C-5A system were selected for entry into TDMS. The data structure for C-5A was modified to take advantage of hierarchical structures allowed by TDMS. Other changes resulted from evaluation of the LUCID data structures (see Section II). Appendix VIII is a list of the C-5A data elements for TDMS. Appendix IX contains the definition of each of these elements.

User Terminology

Ideally, the user of a data system should be able to access and receive information in his own terminology. Queries that must be phrased or computer responses that must be interpreted through the use of handbooks or with the assistance of a systems specialist defeat the purpose of timely retrieval of information. For the purpose of the research, user terminology is generally considered to be the terminology employed by the generators of the task data entered into computer storage. With the exceptions of the standardization of the vocabulary used to express various items of information and the conversion of all expressions of time into minutes, the form of data as received is not altered before entry into the computer.

For the most part, information required to adequately express human performance is highly textual in format, e.g., phrases and sentences, and requires a processing system that can efficiently store and manipulate large volumes of alphanumeric data. LUCID and TDMS are especially efficient in terms of manipulating this textual information. This enables a user to qualify retrieval of information with familiar terminology and to retrieve program-generated responses in a similar, readily interpretable format.

User-Oriented Query Language

The purpose of a user-oriented query language corresponds closely to the objectives of the preceding discussion on user terminology. The intention of a user-oriented query language is to enable a user to directly access the data pool without having to consult a systems expert or a detailed handbook regarding system operations and restrictions. The more closely the query language approaches the terminology in which a user normally references his data, the easier it is for him to use the system.

LUCID provides the experimental system with a query language that is easy to use and easy to learn. The vocabulary consists of relatively few commands and modifiers, which can be combined to form highly selective requests for retrieval of information. TDMS provides the same type of language, though it is slightly more detailed because of the larger number of operations TDMS can perform. Requests are entered to either system on an on-line keyboard console, and immediate on-line response is provided by the retrieval program.

When the data elements were established for each of the data bases in the data pool, each element was assigned a descriptive name that clearly identified the information to be contained in that element. When formulating queries, these elements are referenced by name to indicate, to the retrieval program, the data to be retrieved and the qualifying to be done. A formulated retrieval request is a readable, self-explanatory statement. For example, to retrieve tasks performed by the navigator during preflight operations of the C-5A aircraft the query,

PRINT TASK WHERE (PERSONNEL TYPE) EQ NAVIGATOR
AND (MISSION PHASE) EQ (PREFLIGHT OPERATIONS)

retrieves from the C-5A data base a list of the tasks. The parentheses in the query example are required by the LUCID retrieval program to delimit names of data elements and data values that require more than one word to express. This restriction does not exist in the TDMS retrieval program. The query language for both systems also provides a method of using system-defined synonyms when formulating retrieval requests. Use of the short synonym names, usually two or three characters in length, facilitates the entering of what might otherwise be lengthy retrieval requests through the keyboard of the on-line console.

Data Bank Structure

The requirement to provide an operational capability to add and delete elements of data from the experimental data pool in response to changing system requirements is recognized as a very real and difficult problem. Like updating, it requires a sophisticated processing mechanism, as well as a manual control mechanism to assure the proper and timely use of the capability. Procedures must be provided, for example, to assure that users of the system are aware that a particular store of data has been restructured. The problems of restructuring in an operational environment have not been fully explored during the current research.

Because of the controlled environment in which the PSES is exercised, procedural control of the restructuring necessary for the experimental data pool during the course of the research was not a problem. The restructuring process itself, however, was extremely time-consuming and involved. Even though it was known at the onset that LUCID did not provide any automated method of adding, deleting, or rearranging elements of data within the data pool, the restructuring problems were considered minimal. Some restructuring occurred as the research progressed and it became apparent that the magnitude of this effort was clearly underestimated. The procedure that must be followed in order to restructure any or all of the data pool is to redescribe the data base being restructured and to reenter all data for that data base into storage in accordance with the new structure. In some instances, large volumes of previously prepared input data had to be completely redescribed before they could be reentered into storage.

TDMS is expected to provide much more flexibility and ease of operation in the restructuring of data. The ability to add, delete, or modify elements in the data base will be included in the defining operation of TDMS.

Update

The requirement for updating procedures in an operational data handling system has not been explored in depth. Conceivably, updating will be required on a nearly continuous basis to provide reasonably current information. Large scale maintenance of data files as opposed to selective on-line updating involving small changes, may be a regular occurrence. Assuming that the requirements for updating can be established for an operational system, the development of procedures to govern the updating is, in itself, a difficult task. In an operational data system,it would be necessary to designate individuals to assume the responsibility for the updating and for deciding how it should be conducted.

Requirements for updating information within the framework of PSES are more clearly defined. Because of the unscheduled manner in which data are received and made available for entry into the data pool, the experimental system must be able to add small or large volumes of new data to the pool. A provision is also required for the correction of errors that are undetected at the time the data are entered into storage.

The updating capability of LUCID satisfies the requirements of the experimental system. An on-line updating function permits rapid correction of errors and handles deletions and additions of small volumes of data. TDMS will also provide an updating capability and a larger scale maintenance capability.

Cross-System Retrieval

One of the primary requirements of an operational data handling system is to provide the capability of retrieving data from various aerospace systems contained in the data pool. This particular capability requires that adequate procedures be developed and imposed on the data system to assure that proprietary restrictions are respected and that only authorized personnel have complete cross-system access.

The framework of the experimental data pool was created so that system data are arranged and maintained separately, each in its own data base. Both the LUCID and the TDMS retrieval mechanisms permit access to one and only one data base at a time. This is not considered to be a restriction but rather lends itself to the operational concept of controlled access to the individual system data bases. Since the data pool for the PSES was developed for experimental purposes only, proprietary constraints were not imposed on the system. Application of the operational system [illegible] would require restrictions on the use of the various data bases.

Since LUCID permits access to only one data base at a time during retrieval, cross-system queries must be conducted serially. This does not present difficulties, provided the user knows which data bases to query. If, for example, preflight tasks across all pertinent systems are to be compared, it would be helpful to select only those systems actually containing preflight tasks. It would be meaningless to pose queries to totally unrelated bases during the course of retrieving the desired data. In order to facilitate cross-system queries, a special index data base, INDEX, was developed (see Appendix V). This data base provides an insight into the data content of the system data bases. Queries asked of INDEX usually result in a listing of systems. For example, "What systems contain preflight tasks?" would provide a list of all qualifying systems. The data bases can then be queried on an individual basis for more detailed information.

TDMS will operate like LUCID, selecting one data base at a time. While only C-5A data have been converted to TDMS format, as more systems are added to this data pool, an index data base such as the one relating to the LUCID data pool would be established.

Selective Retrieval

It is essential for the user of the operational task data handling system to be able to adequately express his needs for information to the system. This requires: (1) the ability to qualify retrieval with certain conditions, and (2) the ability to indicate the exact information to be presented after qualification has taken place. Either or both of these points can be expanded in complexity to permit the retrieval of one or more pieces of data depending upon the existence of one or more sets of conditions.

The LUCID system permits users of the experimental system to qualify on and selectively present information from any and all data categories that exist in the data pool. Due to its completely cross-indexed data arrangement, all data categories can be qualified upon or retrieved for output purposes with relatively equal processing. In addition, AND/OR logic can be used to combine qualifying expressions. A complete set of relational operators (equal to, not equal to, greater than) and limited mathematical operators (sum, maximum, minimum) are available.

TDMS allows the same options as LUCID with the addition of certain mathematical operators such as exponentiation, multiplication, division, and negation. Although retrieval can be selectively accomplished on the basis of data contained in any and all data categories defined within the framework of the experimental data pool, a problem exists regarding selectivity. The problem is not directly related to the retrieval cabability of LUCID, but rather to the content and organization of the LUCID data pool itself. In order to expedite the preparation of data for entry into the data pool, the finer levels of human performance were treated as groups of actions necessary to perform given tasks rather than treated as individual actions. The result is that some degree of selectivity is lost by the inability to qualify on these individual actions. The actions can be retrieved as a group, but not individually. This limitation has been removed in the data base for TDMS. Information here may be ieved to the level of individual action.

User Controlled Output Format

The operational task data handling system is intended to be of use to personnel representing a variety of disciplines and skills. It is desirable that each of these individuals or groups be able to control the format of retrieved data in order to satisfy their own particular output requirements. A sophisticated user-controlled output capability enables retrieved data to be arranged in the form of finished reports, summaries, etc., that would ideally contain titles, headings, page numbering, variable spacing and line control, security classificaioons and so forth.

The LUCID system does not provide an elaborate formatting capability. The limited capability that it does provide, however, is considered to be adequate for the purposes of the PSES. The normal LUCID output format consists of one or more lines of retrieved data printed on the teletype, with information continuing from line to line. An optional blocked format is also provided that generates blocked, tabular output, including headings. If desired, retrieval information can be written on magnetic tape for off-line printing rather than direct teletype printing.

TDMS contains a more sophisticated formatting capability allowing the user to specify number of lines of uninterrupted output, spacing, level of data to be retrieved, and angled, columnar, or unblocked output.

GUIDES FOR PSES

There is a need for some tool to instruct and assist potential users in the operation of the PSES. Such a tool must contain all instructions necessary for the operation of the computer programs that comprise PSES. An attempt to meet this need has been made by the preparation of both user's and a controller's operating guide (Reardon, 1968).

Instructions for both guides cover the following areas:

- Operation of remote terminals
- Establishing communication with each of the computer programs of PSES
- Formulating user inputs to each of the computer programs
- Interpreting output from each program
- Recovery procedures to be taken when either user or program errors occur during program operations

Both the user's and the controller's guides provide instruction for the operation of the following software components:

- Time-Sharing System -- Instructions are given for establishing and maintaining communication with the Time-Sharing System via a teletype console.

- Querying the Data Base -- Instructions are given for data retrieval and data manipulation.

- Current Awareness -- Instructions are given for establishing a user profile indicating data interests and for matching the profile against new or modified data entering the system.

In addition to the above areas, the user's guide contains a section describing the PSES data pool. This description lists the data elements for each data base, defines each data element and describes the structure of each data base.

The controller's guide contains, in addition, instructions in the following:

- Describing the Data Base -- Instructions are given for establishing a description of a new data base.

- Loading the Data Base -- Instructions are given for loading data into a new data base.

- Updating the Data Base -- Instructions are given for both small scale on-line updating and for the updating of large volumes of data.

Both guides are tabbed for easy use, contain many illustrative examples, and, where applicable, contain actual samples of input and output opposite these examples.

SECURITY AND PRIVACY

The problems of controlling classified and proprietary information have not arisen in the PSES. However, these problems would be a source of concern to everyone involved in an operational system. For this discussion, the term "security" will be used to refer to the storage, maintaining, retrieval, and transmission of Department of Defense classified data in an operational data handling system. "Privacy" refers to similar handling of data which a contractor or the government may wish to protect from the unauthorized observation of other contractors or users. For both categories of information, divulgence could cause serious or grave damage, either to the country or to private contractors.

In an operational data system, both classified and private data are to be handled in the same system; therefore, protection of both types of data must be handled similarly. Steps must be taken to establish, maintain, and protect the desired security and privacy level in the following areas:

- Physical

- Personnel

- Communications
- Software

Regulations for personnel and physical security are well established by the National Security Agency.

Both the security and privacy requirements demand secure communication circuits. Various devices exist to provide secure lines of communication between remote terminals and the computer. Cryptographic equipment is available to safeguard against the accidental or surreptitious divulgence of information. Detailed information on such protection can be obtained from the National Security Agency if a need for such information can be established, e.g., a military contractor who has an authorized need to know.

In addition to providing for control in the areas of physical, personnel, and communications security, the following principles should be observed to obtain security and privacy with software:

- The computer must operate under a monitor approved by appropriate authority. The monitor acts as the overall guard of the system, and prevents access to sensitive information by unauthorized users and operators.
- The computer must have adequate memory safeguards and privileged instructions. These are needed to limit user programs that might be damaging to another user's programs.
- The computer must have appropriate physical security to prevent local override of the monitor.
- All significant events (equipment malfunctions, unauthorized usage, interference, communications breaks or changes) should be recorded by the computer and the operating personnel.
- Operating personnel must be cleared to the appropriate levels.
- Every user must be subject to common discipline and authority.

When an operating system involving classified and private data is to be established, detailed investigation into these areas will take place and the results of such an investigation will be implemented.

SECTION IV

CURRENT AWARENESS

INTRODUCTION

One of the requirements of an operational data handling system (Section I, page 4) is that such a system must provide for current awareness notifications to qualified users. Notifications would enable the user of the system to remain aware of the current status of data of interest to him without having to continuously query the data base.

A current awareness function notifies the user whenever data of particular interest to him are modified or when new data in his area of interest are entered into the system data pool. Areas of interest are expressed by controlled word lists or profiles. The profiles are automatically compared with incoming data and, if favorable matches occur, notifications are automatically generated. Notifications contain only that information necessary to provide a user with the essential elements of the data input to storage. If a user is interested in obtaining more information than is provided by a notification, the retrieval function of the system is used to obtain the new data.

A current awareness capability was developed for PSES to illustrate the overall concept as visualized within the framework of an operational data handling system. The current awareness techniques thus developed consist of two computer programs. One program is responsible for building profiles. The other performs the matching operation between these profiles and data to be entered into the data pool and generates notifications as appropriate. Both of these programs operate within the time-shared evnironment of the AN/FSQ-32 computer.

PROFILE BUILDING

Development of user profiles is accomplished by program BUILD (see Appendix X). BUILD accepts, as input, data values associated with select data categories. These values indicate the areas in which a user is interested. Interest can be expressed at broad or narrow levels, depending upon the values supplied for the various elements.

Because the matching process compares profiles with data being entered into the data pool, categories used to express profiles are identical to the elements used to define an entry within the data pool as described in Appendix X. The categories used for profile development are:

SYSTEM (Indicated data base to be used)
MISSION PHASE
MISSION SEGMENT
FUNCTION
PERSONNEL TYPE (AFSC and NASA personnel designators)

Profiles are developed in a conversational mode from a remote console. BUILD provides options to the user and the user supplies appropriate responses along with the actual data values that are to be used for comparison during the matching process. It is not necessary to use all categories when developing a profile, but all data values supplied for MISSION PHASE, MISSION SEGMENT, and FUNCTION must exist in the corresponding elements of entries being entered into storage before notifications will be generated. For the categories PERSONNEL TYPE and HARDWARE INFORMATION, BUILD accepts multiple values, any one of which may match and cause a notification, provided that favorable matches occur in the other categories as well. Thus, as in the first profile in figure 10, both hardware items, "throttles" and rudder", are listed as being of interest. Any entry in which either or both of these items of hardware are used is considered acceptable, if all other qualifications for the other categories are favorable. The output of BUILD is a separate file of information for each profile, each identified by a user-assigned name.

Figure 10 illustrates a typical run of program BUILD as controlled at an on-line teletype terminal.

PROFILE MATCHING

Profile matching is accomplished by program MATCH. The program is operated from an on-line console and accepts as input the names of the profiles that are to be processed. The profiles are located in storage and compared, in turn, with a predefined block of task data slated for entry into the data pool. Matching consists of comparing values specified in the profiles by category with values contained in the same elements for each entry of the block of input data. For each entry that meets the specifications of the user's profile, a notification is generated on-line.

Notifications include the following information:

- The system with which a qualifying task is associated
- The name of the task
- An entry number for the task (Each entry is manually assigned a unique number as it is prepared for entry into the data pool. The number can be used as an identifier to obtain more information regarding the entry by use of the normal retrieval function of the PSES.)
- The type of entry (new or modified) ("New" implies that the task is being entered into the data pool for the first time. "Modified" implies that the task already exists in the data pool and is being replaced as a result of a modification. Information about the nature of the modification is briefly outlined in the notification.)

Figure 11 illustrates a typical run of the program as controlled at an on-line teletype terminal. Three notifications are shown.

```
ENTER PROFILE NAME
PROFL1

LIMIT SYSTEM?
YES

ENTER SYSTEM
C-5A

LIMIT MISSION?
YES

ENTER PHASE
PREFLIGHT OPERATIONS

ENTER SEGMENT
TAXI

LIMIT FUNCTION?
NO

LIMIT HARDWARE?
YES

NAME #1=THROTTLES
NAME #2=RUDDER
NAME #3=END

LIMIT PERSONNEL?
YES

CODE #1=1055Z
CODE #2=END

PROFILE COMPLETED.
ANOTHER PROFILE?
YES
```

(a)

```
ENTER PROFILE NAME
PROFL2

LIMIT SYSTEM?
YES

ENTER SYSTEM
C-5A

LIMIT MISSION?
YES

ENTER PHASE
FLIGHT OPERATIONS

ENTER SEGMENT
NONE

LIMIT FUNCTION?
NO

LIMIT HARDWARE?
NO

LIMIT PERSONNEL?
YES

CODE #1=60570
CODE #2=END

PROFILE COMPLETED.
ANOTHER PROFILE?
NO
```

(b)

(Underlined words are sample user entries; all others are program generated)

Figure 10. On-Line Development Of User Profiles

```
ENTER PROFILE NAME
PROFL1

STANDBY
NO MATCH

ENTER PROFILE NAME
PROFL2

STANDBY

1)  SYSTEM - C-5A;   TASK - SET ALTIMETERS
    ENTRY # 200;     TYPE - NEW ENTRY

2)  SYSTEM - C-5A;   TASK - PERFORM 10,000' CHECK
    ENTRY # 205;     TYPE - MODIFIED ENTRY - LOADMASTER INCLUDED IN TASK

3)  SYSTEM - C-5A;   TASK - COMPLETE CRUISE CHECKLIST
    ENTRY # 218;     TYPE - NEW ENTRY

    MATCH CONCLUDED
```

(Underlined words are sample user entries; all others are program generated)

Figure 11. On-Line Generation Of User Notifications

RECOMMENDATIONS

Certain steps remain to be taken to provide a more useful current awareness capability.

Investigation should be conducted to determine the categories of data the majority of users wish to use in specifying data of interest. The investigation could be conducted either by questionnaire or personal interviews with potential system users. The profile-building program can then be further developed to reflect these user-interest areas.

The profile-matching program should be modified, allowing the user to specify either on-line or off-line modifications.

Procedures governing the operation of the current awareness function should be integrated with those for the periodic updating of the data pool. Since the current awareness function operates on data to be entered into the data pool, its operation should take place in the same time period the updating is performed.

SECTION V

VOCABULARY STANDARDIZATION AND THESAURUS DEVELOPMENT

INTRODUCTION

The establishment of methods and techniques for controlling vocabulary is a necessary function of any computer-based retrieval system. The standardization of vocabulary is but one part of the overall research that is based on the assumption that a user-oriented computerized data handling system will help draw human factors specialists and others involved in system development programs closer to needed data.

Human factors task data generated in support of the ALCC, C-5A, and Saturn programs were used to generate the experimental data pool. To keep term proliferation to a minimum while establishing the data base content, a means was sought to maintain adequate control over the vocabulary. One of the most used tools for vocabulary control is the thesaurus. It is designed specifically to alleviate term proliferation through synonym control. The thesaurus allows the data user to assign terms freely, but establishes acceptable terms to facilitate retrieval. These terms are used as descriptors when retrieving data from computer storage. (An acceptable term is one that is assigned as precise a definition as the character of the word permits. An authorized synonym is a term having a meaning identical to or very similar to a particular acceptable term.) Care must be taken to select synonyms that are synonymous with only one acceptable term.

Two related functions of a controlled vocabulary are to avoid indexing identical terms of information under different descriptors and to assure that all information retrieved under a given description is related. When these functions are not fulfilled, available data are denied the user and unwanted information is retrieved. The more related the meanings between descriptors, the greater the care that must be taken to assure that the data are properly indexed.

THESAURUS DEVELOPMENT

A detailed discussion of the methodology and developmental process that led to the development of a human factors thesaurus was reported in Oller (1968). In its present form, the thesaurus consists of a glossary of verbs and nouns, rules governing the use of grammatical categories, and indexes designed to assist the user in making an appropriate choice of terms. For any classification scheme to function successfully, all qualifying terms must be clearly defined and all terms must be mutually exclusive. Without this clarity, the indexers will be confused about where to file an item of information or a related series of information. A controlled vocabulary is imperative for task data bases because they cover a wide range of subject matter and potential users have diverse backgrounds and different information requirements. The controlled vocabulary must be general but at the same time provide the capability of expressing a wide range of concepts. Basically, the controlled vocabulary provides the user with predetermined series of defined terms to describe the items in the data base. By providing the user with standardized terms for which the meaning is clearly understood, loose and inconsistent use of terms can be eliminated. The controlled vocabulary reduces the problem caused by synonyms and multiple meanings for a single term by assigning only one acceptable term for each concept. A cross-reference index of acceptable terms is provided to aid the user in selecting proper terms if assistance is required when requesting data. A glossary, containing all descriptors, is included as part of the controlled vocabulary. The definitions of all descriptors are controlled by the gloasary. Both the cross-reference index and the glossary are arranged alphabetically and are separated into grammatical categories. Cross-reference indexes of acceptable terms and their synonyms are included in the thesaurus to assist the users in selecting a proper descriptor when there is uncertainty regarding the acceptability of a term under consideration. Accompanying the controlled vocabulary is a set of rules that govern usage of various grammatical categories and punctuation. The vocabulary and rules for usage have applicability beyond the experimental data pool and should, with minor modifications, be applicable to most data pools containing aerospace system human factors task data.

The individual components of the thesaurus are examined and the developmental work is described in the paragraphs that follow. Computer assisted capabilities for thesaurus control are also discussed in terms of constraints of the Time-Shared Data Management System (see Section III).

Action Verbs

To develop a controlled vocabulary capable of adequately expressing task statements in a precise, distinct, and unambiguous manner, it was necessary to apply effective control measures on action verbs. Action verbs express a particular form of action, e.g., "operate", "monitor", and "rotate", as opposed to verbs that express only states of being and the grammatical conditions of number, person, and tense, e.g., "is", "am", "are", "was", and "were". It is imperative to control action verbs since they express the action in task statements. The lack of standardization bewween systems and inconsistencies within systems in the use of action verbs was found to be so extreme that it was frequently necessary to rely on the context in which verbs appeared to clarify their meaning. Often, human actions were expressed by verbals (forms of verbs that function as nouns or adjectives) rather than by verbs. Lack of standardization presents difficulties in the extraction of data for non-automated systems, but are intolerable in a computerized fact retrieval system where the need to qualify on individual descriptors is a basic requirement.

Listed below are the sequential steps taken in the development of a controlled vocabulary of action verbs:

(1) The initial step was to extract all action verbs (including verbals) that appeared in the data for ALCC and to record the frequency of occurrence of each.

(2) Based on the frequency of usage, a tentative judgement was made of which

verbs were synonymous.

(3) To keep the verb list within manageable limits, certain types of action verbs were excluded. These exclusions did not limit the types of actions that can be expressed. Specialized verbs were eliminated because the same concept can be expressed adequately and succinctly by a generalized verb plus the noun form of the specialized verb. For example, "chock (specialized verb) wheels", can be expressed by "place (generalized verb) chock in front of wheels". No verbs with the prefix "un" were allowed, e.g., "unscrew". The same concept can be expressed by phrases such as, "remove screw". Compound verbs formed from a noun or adjective were also excluded. This type of verb is generally hyphenated, e.g., quick-freeze or force-fed.

(4) A tentative selection of acceptable action verbs was made on the basis of the highest frequency of occurrence.

(5) A tentative selection was made of terms that were at least partial synonyms to one or more of the previously selected acceptable terms. These were retained in the synonym list, the others were discarded.

(6) Acceptable action verbs were carefully defined to reflect their most prevalent usage in task statements.

(7) A decision was made to express all action verbs in the present tense, indicative mood. The present tense was chosen because it is used to make statements that are generally true, without reference to time. The indicative mood was chosen because this is the usual form of an action verb in sentences or clauses that present facts or make statements. (Subsequent evaluation proved that all actions occurring in the task statements could be satisfactorily expressed in this manner.)

(8) The definitions of the acceptable verbs were examined (item 6, above) to insure that no acceptable verb was a synonym of another. This process was conducted to eliminate possible oversights that could result in acceptable verb redundancies.

(9) Additional synonyms that were not in the task statements, but which are in common use, were added. These terms were obtained from specialized glossaries of terms and from standard dictionaries.

(10) After the acceptable action verbs and their synonyms were standardized for ALCC data, the list was applied to C-5A data. Necessary additions and modifications were made to satisfactorily express a wider range of task statements. The second system required only an 8 to 10% change (mainly additions) to the original list. These changes allowed the verbs to satisfactorily express all actions contained in the task statements. After the verb list was standardized for two of the systems, it was applied to the Saturn data. A change of less than 1% was required to adequately express all action contained in the Saturn task statements.

Although [illegible] were [illegible] from three different aerospace systems [illegible] "fly", "land", "launch", and [illegible] were found to be unique to aerospace systems. It might be necessary to expand the scope of acceptable verbs to accommodate other aerospace system data. For example, since none of the three systems used were weapon systems, action verbs, such a "fire", "range", and "track" would need to be added.

A cross-reference index of action verbs and their authorized synonyms was developed to assist the user in quickly determining whether an action verb under consideration is an acceptable term or an authorized synonym. Once an acceptable term is selected, reference must be made to the glossary for the precise meaning of the term. If the selected term does not provide the meaning desired, the user may refer back to the index or examine the glossary directly to locate an appropriate term. The cross-reference index of verbs (accepted and synonyms) is arranged alphabetically. Acceptable verbs were designated by the letters "AT" and synonyms by the letter "S". Acceptable terms having synonyms were listed opposite the synonym. This form provides quick reference to acceptable terms, as illustrated:

```
Finish (S)------------------------------Complete (AT)
Fly (AT)
Follow (AT)
Furnish (S)-----------------------------Provide (AT)
```

A second index contains all acceptable action verbs having synonyms. The list was arranged alphabetically by acceptable verbs with the synonyms listed directly below the acceptable verbs, as:

Check	AT
Acknowledge	S
Confirm	S
Verify	S
Close	AT
Seal	S
Shut	S

This list provides a quick reference to acceptable verbs having synonyms.

Nouns

The nouns in the glossary were drawn from task statements by the same method used to compile the initial list of action verbs. Since the nouns were drawn from task statements, they were not restricted to hardware identifiers. They encompass a wide range of persons, places, things, qualities, action, and ideas. To give the list greater applicability over a wider range of aerospace systems, system-specific terms were excluded. A glossary of system-specific nouns was recommended to insure the understanding of such terms. There were two primary reasons for compiling glossaries of acceptable nouns: (1) to provide the user with a convenient source for determining the meanings of nouns he is uncertain of, and (2) to assist the indexer in selecting the proper term for indexing an item of data. It also acts as a control device against the proliferation of synonyms.

Rules were developed to regulate the use of singular and plural noun forms and special nouns, such as trade names. No attempt was made to compile a list of synonyms for nouns. Although such a list would be useful in reducing the proliferation of terms, the specific nature of most of the nouns preclude the use of or severly limit the number of synonyms. Nouns, like "aircraft", having a number of synonyms, e. g., "airplane", "aeroplane". and "plane", are the exceptions rather than the rule. In contrast to the generalized meaning of action verbs, the meanings of most nouns are specific to aerospace systems.

Abbreviations

A list of abbreviations was compiled by extracting all of the abbreviations, including acronyms, occurring in the three systems composing the experimental data pool. Many of the abbreviations contained in the list are not in standardized lists of abbreviations, since they often represent a convenient shorthand used by data generators. Care was exercised in assigning meaning to abbreviations because many had multiple meanings. The list provides the user with a reference to the acceptable meaning of the abbreviated terms. Most of the abbreviations should be eliminated and replaced by the full terms. Abbreviations result in far more confusion to the user than can be justified by the shorter form of expression. The only abbreviations that might be retained are those whose most frequent meanings are already standardized, e.g., "CPS" for "cycles per second", or when the meaning is known to a large segment of the user population, e.g., "IFF/SIF" for "Identification Friend or Foe/Selective Identification Feature."

Punctuation

Due to the special meanings assigned to punctuation marks by the computer programs, it is necessary to keep their use to a minimum in or surrounding the descriptor. It is necessary to enclose compound nouns, such as "pulse amplitude modulation" or "rotary switch" in parentheses (or similar techniques) so the program will recognize them as single descriptors.

Pronouns

Pronouns are prohibited. Pronouns are words that represent a person or thing or idea without naming it. Normally the meaning of a pronoun is completed by referring to a noun (called an antecedent) that names the person, thing or idea previously used. This form of identification in a fact retrieval system is unacceptable since the order or sequence in which the [illegible] retrieved cannot be predetermined. Therefore, the computer cannot know what the antecedent of a pronoun is.

Adjectives

Although adjectives were not eliminated, they were relegated to a position of little significance. Little need exists for words that make the meanings of nouns more precise because the nouns are already precisely defined. Also, compound terms such as "ground support equipment" are considered as single nouns, instead of two adjectives "ground" and "support" modifying the noun "equipment". This convention was adopted so that compound nouns would be treated as single [illegible] by the program. [illegible] may appear in the context of the data retrieved, but are not used as qualifiers for retrieving data.

Adverbs

Since the action verbs are precisely defined, there is no need for words that modify verbs. Adverbs may appear incidentally in the context of retrieved data, but will never be used as qualifiers for requesting data from computer storage.

AUTOMATION OF THE HUMAN FACTORS THESAURUS

The research work associated with the development of the human factors data thesaurus has revealed that it is possible to partially automate thesaurus functions within the constraints of TDMS (see Section III). A computer assisted capability for thesaurus control would provide the user with useful assistance when making requests by reducing the amount and frequency of reference to the hard copy thesaurus. The vocabulary of acceptable terms, their definitions, authorized synonyms, and rules for usage would be in computer storage. A discussion of the proposed system and the rationalization for its structure follows.

- Acceptable Verbs
  All verbs and their associated definitions are stored in the computer. The capability exists to retrieve only the acceptable verb or both the acceptable verb and its associated definition. Depending on the type of request, one term or the entire glossary of action verbs can be retrieved.

- Authorized Synonyms for Action Verbs
  The cross-reference file of synonyms and acceptable terms is organized so that, depending on the request, any one part or all can be retrieved from computer storage. When a user is uncertain if a particular action verb under consideration is an acceptable term, he requests the answer from the computer. If the term under consideration is an acceptable term or authorized synonym, the acceptable term and its definition are printed out. The definition is included so the user can make certain that the concept is the one he intended to express. This feature is necessary because, in common usage, the same word may have several meanings and may be a synonym for several terms. If the term under consideration is not an authorized synonym for an acceptable term, the printout will so indicate. The user must then make additional requests using words he considers synonyms for the original term to locate the desired term. Or, he may speed up the process by referencing the cross-reference index of action verbs for an indication of an acceptable term. If both methods fail, the user then examines a copy of the glossary of acceptable verbs to locate the appropriate action verb.

- Rules Regulating Action Verbs
  The mandatory and recommended rules governing the usage of action verbs are

[illegible] rules when [illegible] requests for data from the computer will res[ult] in an error notification. For example, if a subtask were being inpu[t] to the computer, and the first word was not an acceptable verb in the pre[se]nt tense, was misspelled, had an "s" on the end, or was a gerund, the input would be rejected and an error message generated, indicating the first word was not an acceptable term. On the other hand, if the first word of a subtask was an acceptable term, but not an appropriate term for expressing the action described, the program would be unable to detect the error. Errors of this nature must be detected manually. If an additional acceptable action verb, authorized synonym, or invalid synonym were to appear within the context of the subtask statement, it would go undetected by the program since it recognizes only the first word in a task or subtask statement to be an action verb. The actions described by verbs appearing within the context of the statement are lost since they cannot be selectively retrieved. This type of error also requires manual detection for corrective action.

- Acceptable Nouns
  A capability must exist to either retrieve the acceptable nouns separately, or with their associated definition. Depending on the type of request, single terms, or the entire glossary of acceptable nouns must be retrievable.

  When a new noun not having an authorized synonym occurs in the data to be indexed, it can be added, with approval by the information specialist or some other responsible person. In order for a new noun to be added to the glossary of acceptable nouns, it must first be adequately defined.

- Cross-Reference Index of Acceptable Nouns
  The index of acceptable nouns and their authorized synonyms is structured so that any one part or all can be retrieved. If a user is uncertain whether a given noun is an acceptable term, he can query the computer for the answer. Assuming the noun to be either an acceptable noun or an authorized synonym, the acceptable noun and its definition are retrieved. The definition is included so the user can determine if the noun expresses the desired concept. If the term under consideration is neither an acceptable term or authorized synonym, the computer generates an error message or similar response. The user may then choose to make additional requests using terms he considers synonyms for the original term, to [illegible] the proper acceptable term. If both of these approaches fail, the user must examine the glossary of nouns to locate the desired term.

- Rules Regulating Acceptable Nouns
  The rules governing the usage of acceptable nouns must be organized so that, depending on the type of request, the user can retrieve any one or all of the rules.

- Pronouns
  Inasmuch as pronouns are prohibited, their inadvertent use will either re-

sult in an error message or go undetected by the computer programs. For example, an error message is generated if a user inputs the pronoun "he" when requesting data on a task performed by the pilot. The error message indicates that this term is not a valid descriptor, because it is neither an acceptable noun or an authorized synonym.

- Adjectives
  Presently, there is no need for automated assistance in handling adjectives, since they are not used as qualifiers during retrieval. This condition may change with the application of faceted classification. In this classification scheme, attributes are one of the facets or fundamental points of classification (see Section VI). Adjectives such as "simultaneous" and "synthetic" may be used to express common attributes. If automated assistance for handling adjectives becomes necessary, it should take the same form used for action verbs and nouns.

- Adverbs
  There is no need for either glossary or rules governing adverbs since they are not recognized by the programs. If an adverb is inadvertently used as a qualifier, an error message is generated indicating that the term is an invalid synonym.

- Abbreviations
  The acceptable abbreviations and their meanings must be organized so that any one or all can be retrieved.

- Rules Regulating Abbreviations
  When an unauthorized abbraviation is used, the printout must indicate that the abbreviation is invalid. The user must then apply the unabbreviated term because no synonyms for abbreviations exist. In all instances, the full term can be used, even when an authorized abbreviation exists.

- Nomenclature Codes
  A capability must exist to retrieve any one or all nomenclature codes from the computer storage, depending on the type of request made. This allows the user to request hardware data by name or by any appropriate designator, such as a federal stock number, AN designator for electronic equipment, or Department of Defense uniform designation for missiles, rockets, and aircraft. It is also possible to request the appropriate designators for given units of equipment. If a user requests data on a unit of equipment by a hardware code and receives a reply that no such number exists, he then requests the data by the equipment name.

- Rules Regulating Punctuation
  The organization of the file must be such that any one or all of the rules can be retrieved, depending upon the type of request made. Mistakes in punctuation can result in serious errors, but these are usually determined manually. It is necessary to enclose compound nouns in parentheses (or similar technique) so the computer can recognize them as single descriptors. Failure to use parentheses can result in errors and still be legal. For example, when data on "Doppler radar" is requested and the term is not

enclosed in parentheses, data on all types of radars are recovered because radar is a valid descriptor by itself, whereas "Doppler" is not. If terms, such as "estimated time of arrival" are not enclosed in parentheses, the request is rejected and an error message generated indicating an invalid term. This is because none of the four words in the compound term are themselves valid descriptors. Manual quality control must be exercised when loading the data base, because the failure to enclose a compound term like "Doppler radar" in parentheses results in the partial loss of the data.

SUMMARY

The activities that led to the development of vocabulary controls for the PSES and associated research are summarized below:

- Glossary of precisely defined action verbs--This glossary contains approximately 130 generalized action verbs, which express human actions in aerospace systems. Most of these terms are sufficiently general in nature that they can be applied to task statements regardless of the type of system.

- Glossary of non-system specific nouns--This glossary contains approximately 300 nouns used as descriptors for the three aerospace systems that compose the experimental data pool for the PSES. The glossary, because of its non-system specific nature, is capable of forming the nucleus for a glossary of nouns for any aerospace system.

- Rules regulating selection and use of action verbs--A detailed list of mandatory and recommended rules was developed for the selection, use, and modification of action verbs. These rules are used to minimize the inconsistencies in the meaning of action verbs and to reduce the loss of data in the retrieval process. They also allow action verbs to reflect common meanings, while eliminating, as far as possible, the inclusion of jargon.

- Rules regulating selection and use of nouns--These rules and guidelines are not as detailed or as numerous as those for verbs because of the greater simplicity in regulating the usage of nouns.

- Rules pertaining to other grammatical categories, punctuation, nomenclature and abbreviations--These rules are brief. Grammar, punctuation, nomenclature, and abbreviations are simple to regulate and are of less importance than those governing the use of action verbs and nouns.

- Review of controlled vocabularies and rules for usage--The controlled vocabularies of action verbs and rules for usage were reviewed by human factors personnel, grammarians, lexicographers, as well as data generators and potential users. Consideration was given to their comments.

- Modifiers--It was determined that no need existed at this time for glossaries of modifiers. There may be a need for a glossary of adjectives for a faceted classification scheme (see Section VII), since adjectives are used in the expression of attributes. A glossary of adverbs is not needed because they are not used as descriptors.

- <u>Automation of thesaurus functions</u>--The problem of automating the controlled vocabulary and rules for usage was examined. It was concluded that it is possible to partially automate the thesaurus functions.

SECTION VI

TASK DATA CLASSIFICATION TECHNIQUES

INTRODUCTION

Potter et al. (1966) reviewed existing classification schemes having potential uses, at least in part, for classifying human factors task data. Alphabetical indexing, use of links and roles, various forms of subject headings and key term indexes were examined, but analysis showed that these methods did not satisfy the requirements for handling multiple system task data on a factual level. These classification systems were rejected for the following reasons:

- They were limited in scope and would be ineffective for handling a wide range of human factors task data.
- They were oriented towards single systems and would be difficult to adapt for use with multiple system data.
- The techniques were document-specific and not readily adaptable to handling detailed factual data.
- They were too complex or theoretical to be used by a computer system.

The data classification techniques developed for the PSES were based on a logical data framework, hierarchically arranged. The data elements (see Section II) constitute a systematic breakdown of the system mission, and include the personnel-involved task descriptions, task times, hardware, etc. The user is provided with a generalized capability to retrieve specific data or class-related data, but cannot retrieve functional relationships between data items. Not only is there no way in the PSES to identify functional relationships, but there is no way of entering this type of information into the experimental data pool.

Since the classification scheme applied to PSES cannot be used to identify functional relationships, other types were examined, among them faceted classification.

Faceted classification is a method for expressing functional relationships existing between the data items in a task statement. It also can provide information on the effects that given changes to data have on related series of data. It provides information on alternatives that are available to rectify conflicts arising from proposed changes to data. In addition to aiding users by providing a capability to handle functional relationships, it also will assist the information specialists (develops classification) and the indexer (indexes terms). The information specialists is assisted in organizing a data base by maximizing useful relationships between terms. The indexer is also assisted because the indexing terms are grouped into clearly defined conceptual groupings that are arranged in generic hierarchical order.

This classification technique also aids the [illegible] of locating the [illegible] necessary for describing complex subject matter. The conceptual [illegible] are relatively short and can be scanned quickly to find the proper terms.

PRINCIPLES OF FACETED CLASSIFICATION

This discussion presents the general principles of facet analysis and classification and how it differs from existing data classification systems that handle human factors task data. A working definition of faceted classification is. A faceted classification system is basically one in which descriptors* are grouped by conceptual categories and ordered to show their generic relationships. The system is constructed so that concepts are free to combine with one another to express more complex concepts. This contrasts with enumerative systems in which concepts are often tied to other terms. In this situation it may be necessary to examine many classes to find one in which the desired concept is associated with the subject being analyzed.

Typically, classification systems start with the most general level of information in a given universe of data. The information is divided and subdivided until a large classification tree is constructed. (Figure 12 is an example of this technique applied to simplified aerospace system data categories.) Within this framework, each data item must be located at a single position in the structure. This type of classification leads to rigidly grouped categories of data in the network. When starting from the most general level of information, data are divided into many classes and subdivisions, e.g., genus and species. Each subject is divided only one way; that is, all subdivisions of a class relate only to that class. In all classification systems there are logical divisions, but all divisions are not always logical. The following example is a series of facets in which a common form of human behavior can be sorted: ethyl alcohol is a kind of chemical substance, liquid is a state of the compound, potable is a property of it, mixing is an operation performed with it, a glass is a device for carrying out an operation using it, man is a consumer of the mixture and intoxication is a reaction from it. The seven underlined words are facets into which the compound alcohol can be sorted. Rather than to construct one large classification tree, facet analysis starts from the bottom. It first groups terms into categories, arranged laterally, since there are no intercategory hierarchies. The intracategory descriptors are organized into appropriate hierarchical groupings.

This classification technique can be carried to the types of data categories in the PSES. Consider the following:

1. Human factors task statements
2. Action verbs
3. Displays
4. Controls

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*Descriptors are terms selected for inclusion in the thesaurus (see Section V), for use as indexing terms that describe the data contained in the experimental data pool.

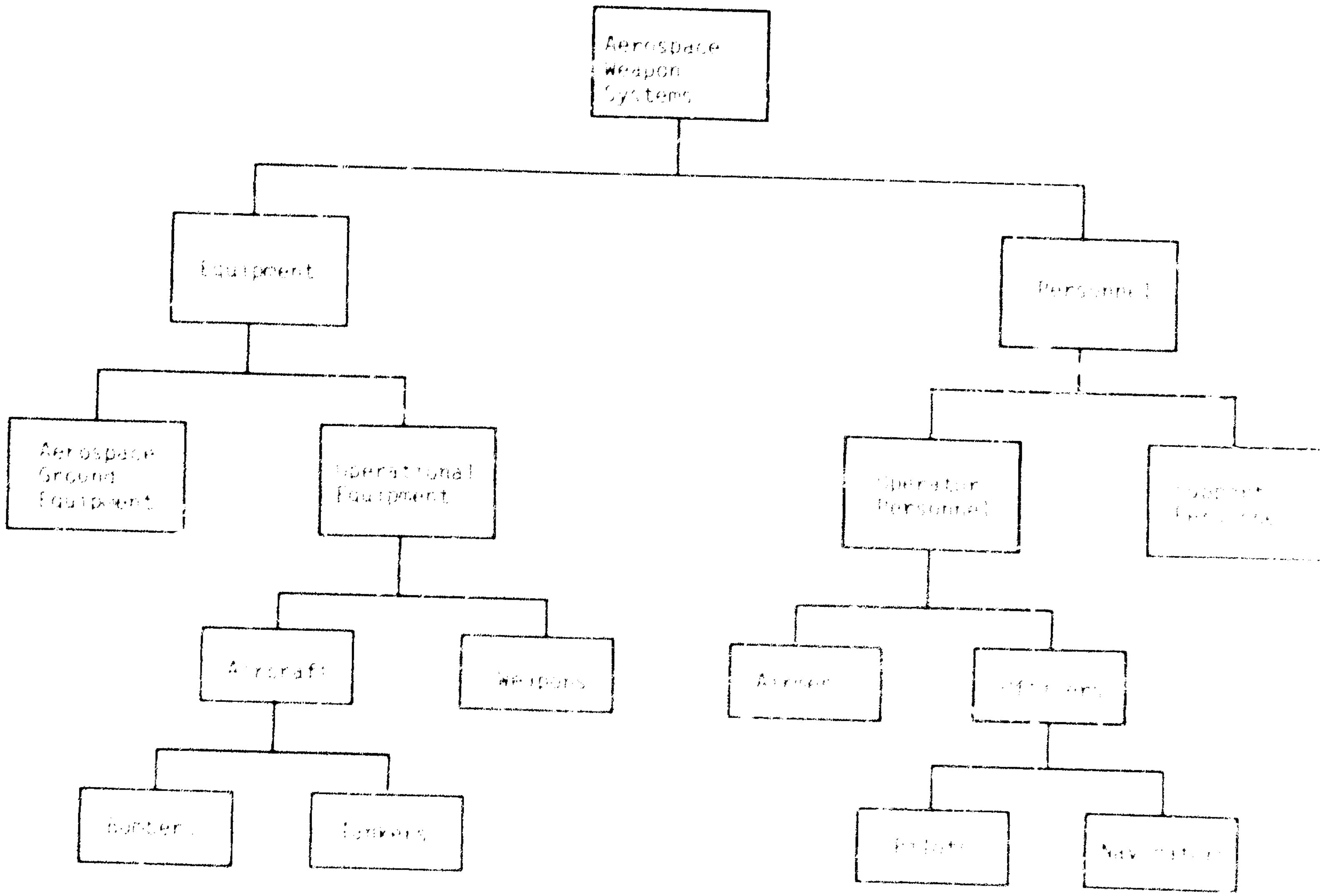

Figure 1. Classification Tree Applied to Simplified Aerospace [illegible] the Data Categories

5. Communication
6. Group activity
7. Training
8. Personnel

These terms cannot be regarded as having been derived from human factors task data by a single characteristic, since they do not share related qualities. Category 2 is an action descriptor, categories 3 and 4 are man-machine interfaces, categories 5 and 6 are human interactions, category 7 is concerned with activities directed to performance improvement, category 8 is the personnel type who performs the task, and category 1 is the task description itself. Although these terms are not collateral members of the category of human factors, they can be sorted into groups, each of which is differentiated on the basis of a single characteristic, e.g., action descriptors. This type of sorting is called facet analysis. Figure 13 illustrates how human factors task data can be sorted into facets (conceptual groupings). The eight categories become subdivisions into which data elements are sorted. The facets are arranged laterally, and all hierarchical groupings are internal to the facets.

The various categories that make up a given classification will reflect the central area of interest. If, for example, the data to be classified involves a new manned aircraft, categories concerned with operational and maintenance personnel, task statements, equipment, training requirements, operational environm t, etc. should be included. The list can be expanded to cover all of the behavioral aspects of each level of interest, as well as the activities associated with manufacture, assembly, and personnel testing.

It will be necessary to apply vocabulary control techniques described in Section V to assure that the terms chosen for descriptors comply with the rules governing word usage. The glossary of acceptable action verbs and nouns should be relied on when choosing descriptors to avoid proliferation of synonyms. Unless these conventions are followed, misunderstanding the meaning of terms will result among the users and data will be lost in the retrieval process. The terms are sorted into appropriate facets--homogeneous groups of terms representing the central area of interest in the data being classified. By way of illustration, the six terms mentioned earlier to categorize human factors task data are characteristic of the divisions by which terms are derived. The characteristics are also logical categories in which to assemble terms. They express certain relations or links between terms, e.g., action descriptors/man-machine interface/personnel, and action descriptors/human interaction/performance improvement/personnel.

In summary, faceted analysis is similar to traditional rules of logical division, but differs in two significant ways. First, the analysis performed to construct the scheme is stricter, since every category must be isolated, every new characteristic of a division must be stated precisely, and new links must be recognized. Secondly, the various facets and categories are not bound into rigid enumerative schedules but are free to combine with each other so that all of the relations between them can be expressed. In essence, by providing a means for combining terms into compound subjects, faceted classification allows for the more adequate expression of the complexity of information.

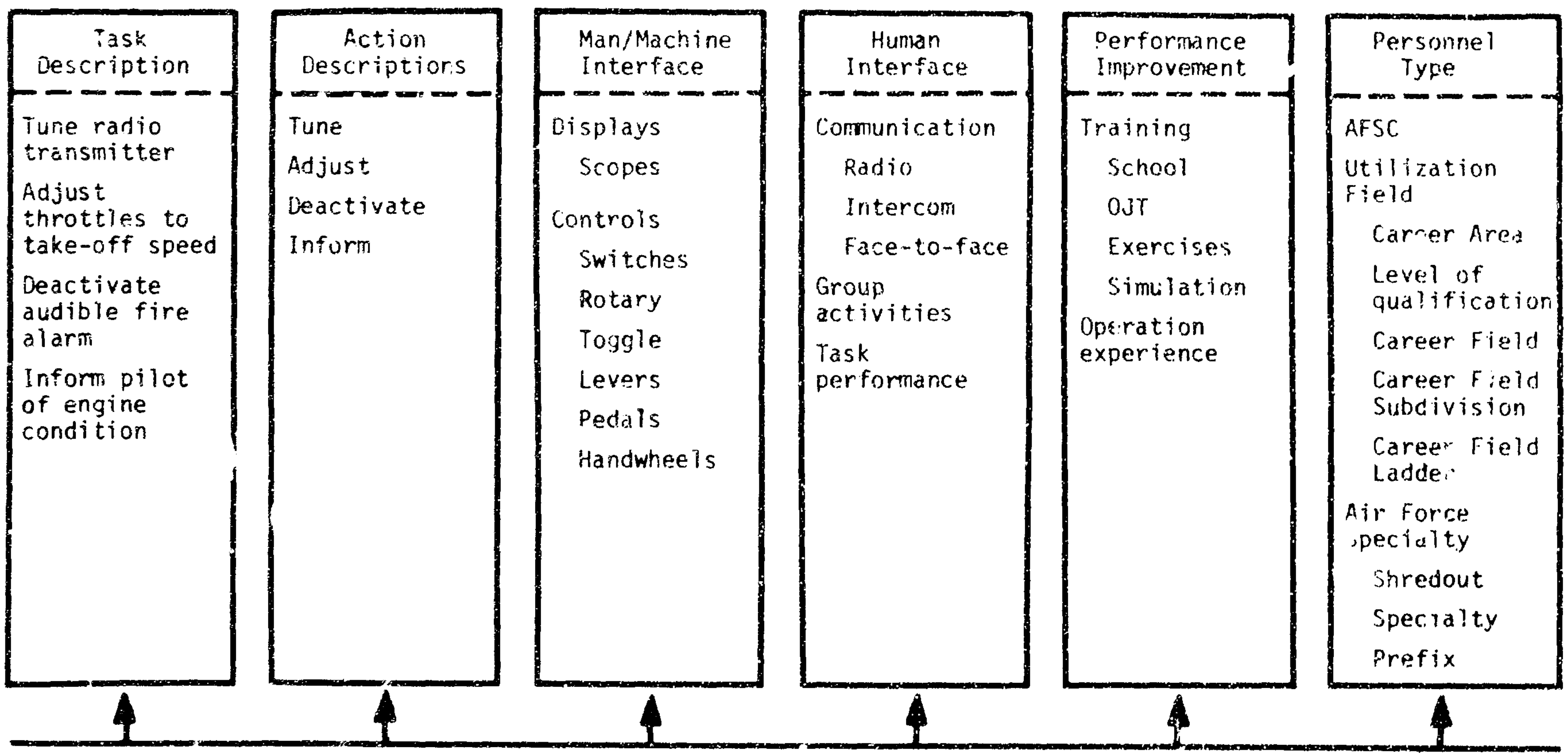

Figure 13. Faceted Conceptual Grouping of Human Factors Task Data

PROPOSED DESIGN OF A FACETED CLASSIFICATION SYSTEM

Faceted classification as described here differs from the original faceted system developed by Raganthan (1957 and 1965) and modified by Vickery (1966). The later form of Raganthan's system was called colon classification, but this term merely refers to the use of colons to separate facets. Their concept of dividing data into a series of related facets was incorporated into the selected approach, but their detailed indexing schedules and classification schemes were not utilized. They were developed for the classification of documents and do not readily lend themselves to the indexing and classification of discrete items of human factors task data. In the selection and organization of facets, greater reliance was placed on the systems developed by the English Electric Company (1961) and Mulvihill and Brenner (1966). These two are library classification systems and are better applied for detailed indexing rather than for book classification. The faceted structure of the detailed tables allows for a fairly logical and concise arrangement of concepts in a complex subject field. This concentration on in-depth classification appears to provide a better point of departure for the classification of factual human factors task data than one more suited to document classification. While these systems are primarily concerned with equipment, personnel, economic factors, etc., some of the concepts can be utilized in the construction of a classification system to handle human factors task data. The proposed design incorporates the principles related to faceted classification described earlier. The data are grouped into a series of laterally arranged conceptual facets that represent the central areas of interest for human factors task data.

The initial step was to develop a series of facets for handling the type of data contained in the experimental data pool. There is a more detailed breakdown of the data elements in the faceted system, but the PSES element list can be expanded to any degree desired. The level of detail is one of degree, not of kind. The faceted system can provide the same type of data retrieval capability as PSES and can be implemented on the Time-Shared Data Management System (TDMS) (see Section III). Due to the limitations of TDMS for handling data that are organized on multiple hierarchical levels, the data must be arranged into a series of rather lengthy entries. A list of these data elements and their definitions is presented in Appendix XI . Each entry includes the pertinent hierarchical data on system, phase, segment, task, and subtask-related data describing the action, personnel, and hardware involved. The faceted system described above is limited to data retrieval; by itself it provides no capability to show the functional relationships that exist between facets. Thus, it can relate one item of data to another, such as action, personnel, and equipment, but cannot be used to determine what effects a change in task sequencing will have on the performance of the tasks.

To provide a means for identifying functional relationships, it will be necessary to add another order of facets. These facets constitute a dependent category that contains information that will modify or expand on the data in the other facets. These facets are called attributes. Attributes are defined as any property or quality of an element in the data base that is a meaningful entity by itself. Attributes consist of information known about the data contained in the data base. To facilitate the user in determining what information is available, each task and subtask must contain indicators that inform the user whether the attribute facets contain information on the elements involved in that particular task or subtask. To identify elements having associated attributes, it will be necessary to query the attribute facets. It will be possible to ask if one or more elements have associated attributes or if any elements have attributes. A minimum of two requests will be necessary to determine what the actual attributes are. The first request provides the names (or numbers) of the elements having associated attributes.

The attributes are limited to those that are direct quantifiable modifiers to elements of task data, such as performance characteristics, training requirements, reliability, and operational environment. A description of reliability should suffice to illustrate the content and use of an attribute facet. Information is provided on the probable error rates associated with different time allowances for the performance of specific tasks or subtasks. It also indicates whether error rates are within acceptable limits. With this type of information the specialist is provided with probabilities associated with time changes and the effect of time changes on the performance of tasks or subtasks. If a time change results in an unacceptable error rate, but the time change was considered to be mandatory, then other attribute files may be queried for assistance. For example, information in the training requirements facet might indicate that error rates can be reduced through additional training. When a tentative solution to the problem has been reached, the economics factor facet can be explored to determine whether the additional training required is economically feasible.

Definitions of representative attribute facets are presented below to exemplify their varied nature and content:

- Economic Factors--Contains the cost of equipment, supplies, facilities, training, transportation, and anything else on which a price tag can be or is placed.

- Location--Consists of geographic locations where the system or any of its facilities might be relocated.

- Operational Environment--Contains a listing of the conditions under which a system's operational support or maintenance operations may occur--it is subdivided into temperature ranges, altitudes, and regions, e.g., land, sea, outer space, etc. The breakdown can be as detailed as the data warrant.

- Reliability and Maintainability--Reliability refers to the probability that a system or any of its human or equipment components will perform a required function under specified conditions, without failure, for a specified period of time--this characteristic applies to hardware and man. Maintainability refers to the characteristics (both quantitative and qualitative) of hardware design and installation, which make it possible to meet operational objectives with a minimal expenditure of maintenance effort (manpower, personnel skill, test equipment, technical data, and maintenance support facilities) under operational environmental conditions in which scheduled and unscheduled maintenance are performed. This facet may be expanded to include repairability and serviceability data. Repairability refers to those qualitative factors that determine the repairability of equipment, including time to diagnose and isolate malfunctions, time to repair malfunctions and place equipment in satisfactory operating condition, manpower and skill levels required to repair the malfunction, and the time the equipment is operating satisfactorily without requiring corrective maintenance. Serviceability refers to that function of equipment design, configuration installation, and operation which results in minimization of maintenance requirements, including the use of special tools, support equipment, skills, and manpower. It enhances the ease of performing maintenance and reduces the expenditure of time and material.

SYMBOLIC EXPRESSION OF TASK DATA

A capability to express statements symbolically will be useful when describing the functional relationships between the component facets of task data. Symbolic expressions provide a method of expressing statements or conditions by conventionalized characters. The symbolic expressions described here take the form of pseudo-algebraic equations, but are, in reality, a convenient shorthand technique for expressing task data and have no direct relationships to mathematics. By their concise nature, symbols can be used to show interrelationships between components of task data more clearly than can be shown in narrative form. The clear-cut and systematic divisions of data in the faceted classification system facilitate the generation of symbolic expressions. This methodology will provide the analyst with the capability to better understand the relationships that exist between the data. For example, he may want to know how personnel are affected by increased periods of activity, how the operational environment affects the performance of the crew and the equipment, whether proper shelf levels are available to maintain its equipment adequately, or any other simple or complex relationships.

Task information frequently changes during the course of system development. These changes can be expressed symbolically. For example, a series of symbolic statements can be used to express prior, concurrent, and subsequent events that exist in task sequences. Other typical changes that occur to a mission time-line, that can be expressed symbolically, are as follow:

- Addition of new tasks or subtasks
- Deletions of tasks or subtasks
- Changes in the time to perform tasks or subtasks, e.g., longer, shorter or different times in the mission
- Addition or deletion of personnel

- Reassignment of existing tasks or subtasks to different personnel
- Change in the sequence in which tasks or subtasks are performed
- Addition, deletion or changes to hardware components
- Change in coordination requirements for tasks performed by more than one person due to some change in task assignment of one or more of the personnel involved in its accomplishment
- A change in the mission of the system, e.g., a change from a reconnaissance mission to a rescue mission may cause a major change in the time-line. Analysts are most concerned with changes of this nature early in the design cycle, when they are modeling and conducting contingency studies.

The determination of conflicts is not simply a matter of locating points in the time-line of a mission where an individual must perform more than one task or subtask or where an equipment component is used by more than one individual during the same or overlapping time intervals. Rather, it is a matter of determining which of these conditions constitutes conflict, since an individual may be able to perform several tasks or subtasks simultaneously. The problem is to determine which ones, if any, are of a contradictory nature. For example, a pilot may be required to monitor a number of visual indicators continually while steering an aircraft and may be required to communicate with a ground station at the same time. The simultaneous performance of these tasks may be within the capabilities of the pilot. But a single task may result in a severe conflict if it requires two individuals to perform mutually contradictory operations on the same unit of equipment. Also, a task or a combination of tasks requiring the same individual to be at two locations at the same time will obviously result in a conflict. The symbolic method of expressing data may assist the analyst to isolate the locus of contradictory operations and in finding means of resolving conflicts.

The terms and structure of task statements and a series of typical modifications to the system and mission profile are presented symbolically to illustrate the range of conditions that can be expressed. Because of its simplicity, a series of changes to a mission time-line was chosen to illustrate the symbology and structure of the statements. A typical task statement expressed in symbols is shown below:

$$C\text{-}5A - FO_c\ [\underline{PCN} - CT_3\ (T15 - 25)]$$

The first group of capital letters and combination of capital letters and numbers appearing in front of the brackets and separated from the other letters by a hyphen represent the system. The capital letters appearing directly after the hyphen indicate a particular mission phase of the system, and the lower case subscript letter(s) indicates a specific segment of the mission phase. In this example, C-5A = the system, FO = the flight operations mission phase, and c = the cruise segment of flight operations.

The positions involved in the task are expressed by capital letters. If more than one position has the same title, a particular one is distinguished by a subscript number. These letters are the first insertions inside the brackets. In this example, P = Pilot, C = Copilot, and N = Navigator.

IT = Independent Task. An independent task is one that involves only a single position in its performance. When a subscript number is added, e.g., IT_1, it indicates the sequential occurrence of the task for a given position since the start of a specified segment of the mission phase. Each independent task has the designators of the appropriate position in front of it, separated by a hyphen, e.g., C-IT_1.

CT = Coordinated Task. Coordinated tasks are those that involve more than one position in their performance. When a subscript number is added, e.g., CT_2, it indicates the sequential occurrence of the task since the start of a specified segment of the mission phase. Each coordinated task has the designator of the performing position in front of it, separated by a hyphen. The positions that are active participants in the task have a dash under their designators, e.g., $\underline{PC}\underline{N}$-$CT_3$. If, in this example, the pilot and navigator are communicating with a ground control station and the copilot listens to the communication, the pilot and navigator are actively involved in the task, whereas the copilot is passively involved.

T = Time. T alone indicates that the time involved is unknown. Any numerical time is expressed in minutes and hundredths of minutes. When T is followed by two sets of numbers separated by a hyphen, it represents the time interval in which a task is to take place, calculated from the start of the mission, e.g., T 15-25. Time followed by a single set of numbers indicates the total time allowed for the performance of the task and does not place the task in a sequence, e.g., T5. Time may also be expressed as "continuous" TC or "as required" TAR. Specified times are always enclosed in parentheses, e.g., (T 15-25) or (T5), whereas all other times are n . Brackets [ ] are used to enclose the tasks and their associated times, e.g., [PCN - CT_3 (T 15-25)].

A superscript number over T of either IT or CT, e.g., IT^4, CT^4, indicates an individual subtask performance, rather than the entire task. In these cases the time is understood to be subtask time rather than the task time.

The following illustrates how the symbolic technique can be utilized for describing and resolving problems associated with the addition of a new subtask to a mission time-line. If a time change was necessary to CT_3, in the original example, it would be necessary to identify the subtasks occurring prior to and after the subtask being changed. It would also be necessary to determine if any other tasks are being performed during this time interval in order to be able to evaluate the effects of the change. For example, if a new subtask is added between CT_3^4 and CT_3^5, it would be necessary to know which of the positions performed these tasks and what time intervals were involved. If the positions and times involved are $\underline{P}$-CT_3^4 (T 17-18) and $\underline{N}$-CT_3^5 (T18-19), then the question is: Are other tasks being performed at least in part between (T17-19)? If, for example, one other task, FO [N-IT_2 (T14-19)], overlapped this time interval, it would indicate that the pilot and navigator are more thoroughly occupied than the copilot. Assuming that the subtask had not been assigned and that an analysis of the facets involved indicated that it could be performed by any of the three positions, then, all other factors being equal, the logical choice for this additional subtask would be the copilot. However other factors might mitigate against this choice. If so, this could also be determined by using the symbolic method.

The symbolic information below the horizontal line refers to equipment. The equipment symbols are E = Equipment, MC = Major component, C = Component, A = Assembly, SA = Subassembly, and P = Part. When the equipment symbol(s) is enclosed in parentheses, it indicates the equipment unit(s) involved in the task. When E appears by itself, the equipment unit(s) affected by a proposed change has yet to be determined. When E is followed by one or a series of letters divided by hyphens, it indicates that these are the equipment unit(s) that may be affected by a proposed change. For example, E-C-A indicates that an assembly to a component may be affected.

To describe a change and its effect to a task, additional symbols are added after the brackets. If the problem were to determine how reliability of performance is affected by a reduction of 5 minutes to task time in the original example, the task statement would now read:

$$\text{C-5A-FO}_C \; \frac{[\text{PCN-CT}_3\ (\text{T15-25})]}{\text{C}} \; (\text{-T5})\text{=R}$$

The change to a task statement always appears after the brackets and is enclosed in parentheses. In this example (-T5) indicates a reduction of 5 in the time to perform the task. The symbols appearing after the equal (=) sign are applied to information about the effects of proposed changes. If more than one, they are separated by hyphens. In this example, R = Reliability.

Changes of a broad and far-reaching nature can also be expressed symbolically. If there is no symbolic data enclosed within the brackets [ ], it indicates that the proposed change produces no effects. If the change statement does not include symbols for mission segment, it means that the change affects the entire phase. If the symbols for phase are also missing, it indicates that the change affects the entire system.

To reiterate, the use of symbolic expressions provide:

- A concise method for expressing task data
- A concise method for describing changes to task data and for describing the conditions surrounding these changes
- A method for determining the effects of changes and how to rectify conflicts arising from these changes

* A simplified and exacting method for requesting information from computer storage

* A method for saving time

SUMMARY

In summary, the type of faceted classification scheme proposed to handle human factors task data is one that: (a) has homogeneity of concepts occurring within the same category, facet, or subdivision; (b) has a one-place-per-concept philosophy; (c) stresses the synthetic capactiy of terms to combine with one another to express more complex terms; and (d) provides the capability to express functional relationships between certain data. By providing the system with a category framework, it is simple to assign unique placement to concepts occurring in the schedules, since they are classified according to their basic characteristics.

The vocabulary that results from faceted analysis can be used for initial indexing and for querying the data base. Facet hierarchies can also facilitate the conduct of generic searches. It will be simpler and less costly to construct and use a facet classification system than an enumerative system. Also, facet analysis provides a technique of vocabulary construction that has the advantage of being explicit and can be precisely described, communicated, taught, and analyzed. It can also be readily changed to accommodate modifications and deletions.

SECTION VII

DATA ANALYSIS AND SIMULATION TECHNIQUES

INTRODUCTION

The techniques employed by human factors specialist in refining task information into useful products, such as manning estimates or the determination of skill requirements, are often the result of analytical and simulation procedures. Such procedures are highly amenable to computer application. It follows that if data are easily accessible from computer storage, various techniques can be applied to refine the data into needed products. Research on analysis and simulation was conducted to determine the needs of aerospace system programs and the analysis and simulation software design necessary for integration in a user-oriented computerized task data handling system. Preliminary research conducted by Hannah et al. (1965) and Whiteman (1965) indicated that anticipated users of analysis and simulation techniques extended from program level managers to non-managerial specialists in aerospace system development programs. Hannah et al. (1965) concluded that computers were not being used in many instances for the purpose of analysis and simulation because of the high cost of computer technique development, the extensive time required in the programming effort, or the inaccessibility of computers. They also concluded that current trends in the application of analysis and simulation techniques in aerospace system design and development have resulted in the generation of many diverse techniques that are specific to particular systems. Thus, the question for research was: Can analysis and simulation techniques be developed that will provide for the maximum numbers of users with the maximum levels of application and specificity. This approach would reduce cost and time by eliminating redundant development of analysis and simulation techniques and computer porgrams.

The current and potential uses of computers for conducting analysis and product simulation were assessed through the distribution of questionnaires during the preliminary research period (Hannah et al., 1965). Many respondents to the questionnaire indicated that simulation functions were either being performed in their organizations or could be performed for determining human performance estimates, equipment performance estimates, manning estimates, hardware requirements, and cost estimates. Computerized simulation techniques have also facilitated the design and development of training devices, the investigation of various subsystems within systems, and the estimation of system reliability.

Whiteman (1965) indicated that almost one-half of current computer processing is devoted to analysis. As in the case of simulation, it was shown that there was also a diversity in the application of analytic techniques. However, in analysis the redundancy is not in the development of analysis techniques, but rather in the development of computer programs. Typical analyses are: multiple regression, correlation analysis, factor analysis, and analysis of variance. Techniques need to be developed that allow a user to access analysis programs, such as these, or to develop his own techniques in a user-oriented environment.

With regard to simulation, Whiteman (1965) recommended the development of a computer language especially oriented to human factors data. The language should provide facilities for: (1) selecting data from a master data file, (2) processing selected data, and (3) generating reports. In view of current research, the question of concern is the feasibility of producing a simulation language that is tailored to human factors information. This could be achieved; however, it would be very costly due to the extensive man-hours necessary to produce such a tool. Current research found that there are many simulation languages already in existence. Thus, existing simulation languages should be evaluated and, if possible, one should be chosen that complies with those attributes Whiteman recommended.

The initial effort beyond the preliminary research approached this problem by examining task data for their fundamental analytical properties. This effort, reported in Potter et al.(1966) dealt primarily with the human factors task data to be included in the experimental data pool. Several problems were investigated: identification of the quantitative and qualitative characteristics of the data, identification of the measurement characteristics of data, selection of standard mathematical measurement units (English vs. metric units), and identification of interfaces with other research areas, such as data classification and vocabulary standardization. Final solutions to these problems must be sought in conjunction with the overall development of objectives and detailed specifications for PSES analysis and simulation functions.

OBJECTIVES

The research was intended to answer questions, such as:

- Do current analysis and simulation techniques lend themselves to pooling into a generalized data handling system within a user-oriented environment?

- Is it possible to develop a general simulation technique or should a store of simulation techniques be provided?

- Can analysis and simulation techniques be incorporated as an integral function of a user-oriented data handling system?

- Can generalized analysis and simulation techniques in a user-oriented computer environment lessen the need to continuously develop system-specific techniques?

- Can the data base content and computer programs provide ready access of information for both analysis and simulation?

- Must modular routines be used to provide ready access of information for both analysis and simulation?

- Must new techniques be developed in order to provide an analysis and simulation requirement within a user-oriented computerized data handling environment?

- Are there other research areas that have significant implication upon the development of analysis and simulation techniques within a data system, such as data organization and vocabulary control?

These questions led to the generation of the following research objectives:

- Investigate current analysis and simulation techniques and their applicability to a computerized data handling system in a user-oriented environment
- Define the categories of data for analysis and simulation which provide the input to analysis and simulation techniques
- Select an analysis and simulation technique which would interface with the relevant data handling research efforts and the system
- Develop standard data formats that are amenable to analysis and simulation techniques
- Develop generalized analysis and simulation techniques that are flexible enough to satisfy the needs of aerospace system development programs

APPROACH

Analysis

An analytic capability must be provided as an integral function of the total user-oriented data handling system if the objectives of the research are to be realized. Specifications must be developed that deal with the sources of input, the manner in which analysis can be achieved using these input sources, and the manner in which outputs can be obtained. The problem is in designing a set of programs for the throughput stage that will allow for such capabilities. Thus, the problem inherent in the design of such a system is the development of specifications dealing with the manner in which data are input, throughput, and output in the data handling system. The approach taken was to investigate existing analysis programs that achieve the objectives and philosophy of the research.

Figure 14 illustrates an integrated concept to analysis. This concept allows for data inputs for analysis from several sources and for the outputs of analysis to be distributed to several sources. This supports the philosophy that analysis capabilities must allow for varying source inputs and varying recipients of outputs, as was indicated by many technical system designers who aided the current research effort.

The sources of analytic inputs shown in figure 14 are similar, and in some cases synonymous, to the recipients of analytic outputs. The data pool input must be compatible with a computerized data handling system software, e.g., [illegible]-TDMS. If more than one data pool is used from which data inputs are

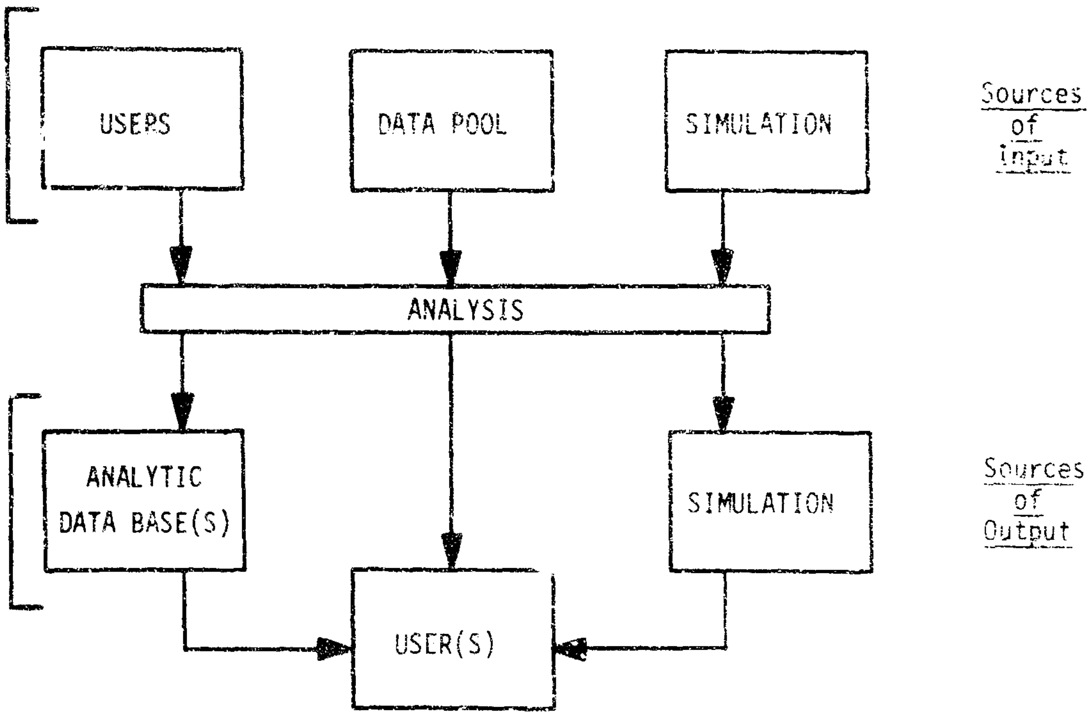

Figure 14. Analysis Concept

drawn, then the additional data pools must be similar in organization to the first data pool for the particular system. These additional data pools might contain information from analyses performed on other systems, which are similar to the system being developed. This is an effort to maintain continuity between different data bases that contain information relevant to a single aerospace system development program.

The second source of input is users. A user might choose to perform analysis on information which is not contained in an existing data pool. The desire would be to provide a capability for users to input data on-line.

The third source of input is from simulation. After outputs have been derived from a simulation, there may be a desire to analyze these outputs. Changes in values may result from simulation and these resultant changes could be identified for input into an analytic data file. The analytic data would contain results of various analyses and simulations and the formulas from which the results were derived.

Just as there are several sources of input to analysis there are also several recipients of analytical outputs. As shown in figure 14, the recipients of outputs are the system users, the analytic data base, and simulation. In a gross sense, all outputs are received by users, since the results of analysis are performed because they are desired by a user. The outputs of analysis serve as feedback to a user by providing easy and rapid access to data upon which decisions can be made.

The second recipient of analysis output is the analytic data base content which represents a subset of data chosen for analysis from a data pool. Those values derived from the application of analysis are entered into the data base whenever a user desires. They can be entered as new element values or used to update existing values of elements.

The third, and perhaps the most important recipient of analyzed data in terms of demonstrating the integrated concept in a user-oriented environment, are the simulation routines. To illustrate, the values obtained from logical, arithmetic, or statis ical operations might be obtained from the analysis programs and used as inputs to the simulation programs. If these obtained values have alr ady been processed in a manner which is amenable to simulation input, there would be no need for users to generate processed data for simulation input. Users could elect to input the pre-processed value directly into the simulation by use of a program that would call these values into the simulation program thus eliminating one additional possibility for human error.

The concepts described above established preliminary specifications for selecting a set of analyses programs that lend themselves to integration in a user-oriented environment. The selected programs must be investigated for their compatibility with the software, the hardware, the philosophy of a user-oriented environment, and the needs of human factors specialists. If an analysis technique is to be selected for implementation in a user-oriented environment, it must be compatible with the concept of time-sharing; not restricted to implementation on any specific computer; have a capability of handling data stored in a large data file; be relatively easy to operate; provide a capability to process logical, arithmetic or statistical operations; and be written in the JOVIAL language in order to be compatible with the computer language of PSES.

The investigation led to a system which hopefully would meet the requirements established in the approach and the objectives. This system is TRACE III, presently being developed by System Development Corporation.

TRACE III operates in a time-shared mode and has a specially-designed user-oriented command language that provides manipulation of analytic data. It provides a means for users to organize data in a manner which is most appropriate to their specific analytic needs. This capability in TRACE III provides for rapid access from the data pool of the specified data upon which a particular analysis is performed. TRACE III reduces the total computer processing time by restricting the operation to subsets of data elements necessary for a series of specific analyses. It is necessary to construct a data file according to TRACE III specifications in order to perform analyses on those data called from the larger TRACE III file and placed on a smaller file. It also provides an automatic updating capability that fulfills the user's need for manipulating his most current information and permits him to include the results of prior analysis in future manipulations. These capabilities in TRACE III fulfill the analytic requirements of retrieving data from a data pool and allowing users to input data not contained in a data pool. There is also the possibility of developing a capability that permits the user to input results from simulation processing. Through these processes, TRACE III provides the users with the capability to interact with the analytic programs in a user-oriented environment. Some of the capabilities of the TRACE III analysis system include: (1) a system of computer programs operating in a time-sharing mode, (2) performance of data manipulation functions normally assigned to a data clerk, such as the derivation of new variables from existing variables, (3) automatic updating of the data base with derived information, and (4) data manipulation without the time-consuming task of writing specific programs for this purpose. TRACE provides the capability to perform often-used statistical operations and permits the expression of more complex and less-used operations without any programming effort. These analyses are expressed by the user in the simple format of the TRACE III command language. Once analytic routines are written by a user, they can be stored in a file for later recall. This feature exemplifies another reduction in time expended by the users in processing their data. TRACE III provides an analytic capability which can be considered as part of a total data handling system. It allows the three sources of input discussed earlier to interact with its programs in a manner which is quite desirable and would meet many of the requirements of aerospace system development programs. Conversely, the results derived from analysis can be distributed to the three recipients of analytic output.

In addition, there are two communication options by which users may specify their requirements. The users can operate TRACE III using either its command language or its discursive language. The latter method of addressing the system leads the user step by step through the process of specification. After the process is specified, using the discursive language, the command language corresponding to that process is presented to the user and passed on to the TRACE III compiler automatically. The TRACE III system instructs the user in the construction of short, precise requests.

In summary, the TRACE III system provides an analysis technique which can be used in a user-oriented environment. It permits users to express formulas in a manner which does not require programming effort by the user and is simple to operate. It allows users a greater interaction with the data and is designed to be compatible with the time-shared PSES. A user is not restricted to rigid preprogrammed analysis; rather, through the command language of TRACE III, he will be allowed to express logical, arithmetic or statistical operations of any complexity. It also support the concepts envisioned in the analytic approach and should be considered for more thorough investigation as the possible technique to be implemented in the PSES.

Simulation

Experience has demonstrated that simulation capabilities generated for one system often cannot be readily applied to other systems or even different developmental phases of the same system. In developing a simulation capability, one of the fundamental questions to be answered is: What is the objective to be fulfilled by simulation? Ideally, a general simulation capability should be applicable to the resolution of a broad spectrum of problems, such as:

- Determination of the requirements for selection and training of system personnel
- Evaluation of man's roll and effectiveness in systems and subsystems
- Evaluation of man's capacities in varying environmental situations
- Determination of the procedures and requirements in regard to personnel, operation, and maintenance needs

The development of a simulation capability that would resolve the multiplicity of problems that are encountered in aerospace system development programs should be considered a long-range goal. However the immediate goal should be the development of a limited simulation capability that is meaningful and in consonance with the other developmental activities of the PSES research program.

One of two basic approaches can be followed in the development of a simulation capability; a closed-end approach or an open-end approach. The closed-end approach is illustrated in figure 15.

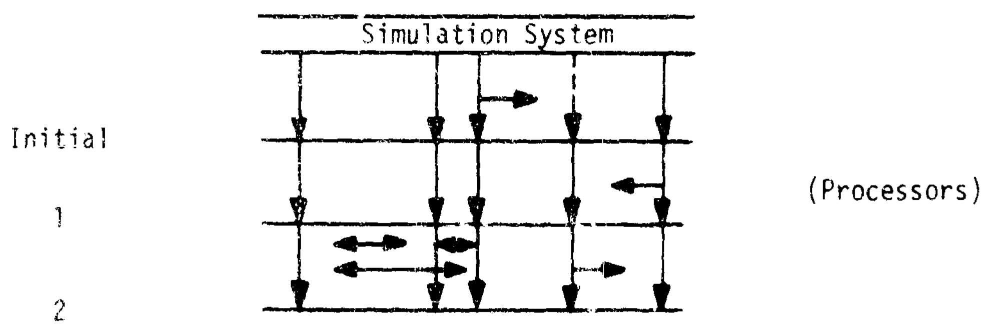

Figure 15. Closed-End Approach to Simulation Development

The horizontal arrows in figure 15 represent simulation processing techniques which are developed in parallel dependent increments from the initial state through the first and second stages to complete development of the simulation processing techniques. In this approach, the simulation processing techniques are not independent of each other. Since no one technique is started or completed before all the techniques are started, the work effort remains at the same level of development. Because of the development of all the simulation processing techniques and the interfaces between them take place concurrently, as represented in figure 15 by the vertical arrows, the incorporation of a new simulation processing technique into the simulation program may require extensive expenditures of time and funds. Therefore, this approach presupposes that all the simulation processing techniques are defined and their algorithms known before initiating development of the simulation system. The advantage of this approach is in resolving well-defined problems. In this case, all work and cost expenditures are channeled into a concerted effort to promote the resolution of the problem.

The open-end approach is illustrated in figure 16.

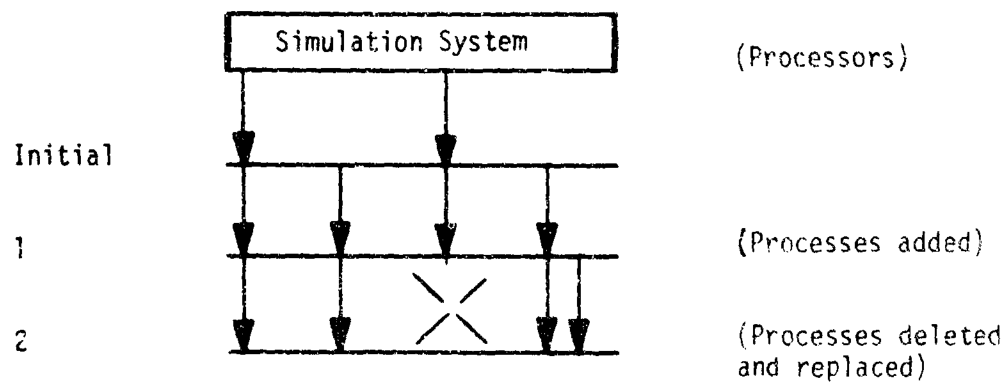

Figure 16. Open-End Approach to Simulation Development

The open-end approach involves postulating simulation goals and developing simulation processing techniques and/or selecting simulation processing techniques from off-the-shelf inventories that can be used to achieve the stipulated goal. Each processing technique incorporated into the simulation program is independent of every other processing technique and any intercommunication of information between the techniques utilizes the user as the communication channel. In this approach, different processing techniques for each established goal can be in various stages of development. The development of each simulation processing technique can be correlated to the state-of-the-art in simulation technology, the incorporation of new information items into the data pool, past experience gained from users concerning the utility of each simulation technique, changes in user needs and requirements, and funds available for development. Furthermore, the addition of new processing techniques can be undertaken at a relatively low expenditure of time and funds because of the lack of automatic cross-communications between processing techniques.

One major simulation problem can be illustrated by considering its solution through the application of these two approaches. This is the problem of data acquisition and selective retrieval for simulation. Selective retrieval of data specifically for simulation is the first prerequisite for any simulation program. The data must be structured and organized in a manner acceptable for input into the specific simulation processing program. This structuring can be accomplished either by organizing the computer file structure in accordance with simulation requirements or providing computer programs which restructure the data after retrieval. Figure 17 is an example of the closed-end approach as it is applied to this problem.

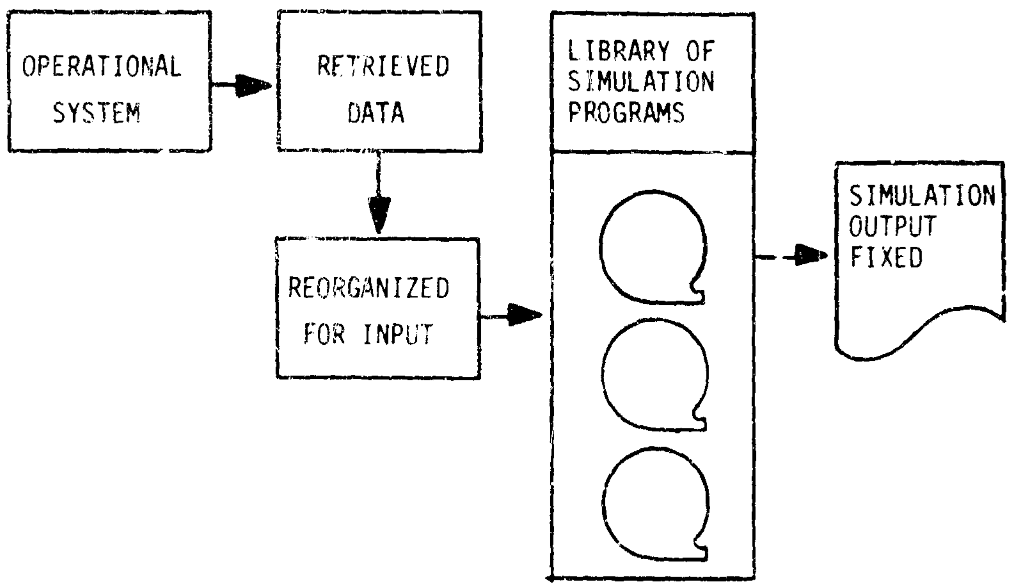

Figure 17. Example of Closed-End Approach to Simulation

Utilizing this approach, the user is restricted to a specific library of simulation programs and would not be permitted to deviate from the library of programs available. Figure 18 illustrates the application of the open-end approach.

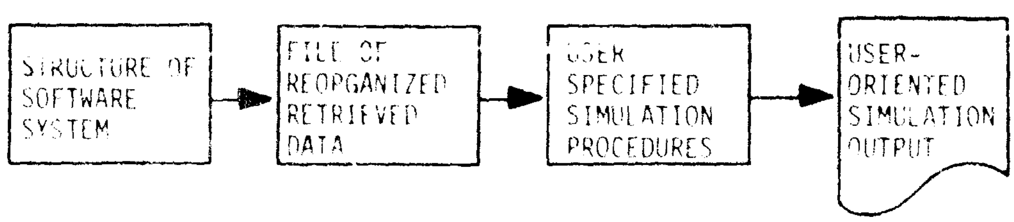

Figure 18. Example of Open-End Approach to Simulation

In this approach the operational system would consist of a structure of software programs that provide a file of retrievable data organized in accordance with user specifications. These data are then processed by generalized user specified simulation procedures (program). Under this concept the user loses a specificity that prohibits the accomplishment of some simulations; however, he gains a flexibility that enables him to structure simulation procedures capable of meeting most of his requirements.

A possible disadvantage of the open-end approach is that the user must know the limitations and requirements of each simulation processing technique and may have to accomplish a significant amount of manual labor to effect noise-free communications between processors, particularly when the answer to a query requires the operation of a sequence of simulation processing techniques. However, once the user has been satisfied that a set of simulation processing techniques has demonstrated utility and validity, further development of this set of techniques can be undertaken to approach closed-end development.

Of the two approaches, the open-end approach has greater intrinsic applicability. The development requirements to attain the goals established in this research must be considered as interactive and evolutionary. Since all ramifications of a system and users needs or requirements cannot be predicted, the open-end approach, which allows for growth and expansion at relatively minimum expenditure of funds and time, is recommended for consideration in the further development of the PSES.

In concept, the developmental process should be for the purpose of selecting a set of tools to be used in a simulation system. In this case, a tool is analogous to a simulation processing technique, the central location is analogous to computer storage. The tools selected must depend upon the use to be made of them.

The simulation technique selected must be adaptable to the computer system that is to be used. This task may entail a relatively small amount of time if the technique is already written in some general purpose language, such as Fortran, JOVIAL, or COBOL. In this case, recompiling through a translator may be sufficient. If the technique is available in a machine-language code, more time may be required for its adaptation. If the technique is in the natural language, considerable time may be required to adapt the language to the acceptable program form and to test and check out the program. At least each input/output routine should:

- Provide an interactive capability to display fixed outputs as the result of the operations of the simulation techniques. The user should also be able to specify changes of event ordering within the fixed output capability, whenever the technique's output can be so ordered.

- Provide a capability to permit the user to input and store data that are not contained in the data pool but that are relevant to the operation of the processor to be used.

- Provide a capability to store, on tape or binary disc, any grouping of data and processors that the user may wish to save.

A capability to extract data from the data pool and organize them in a form suitable for use by a simulation program is extremely necessary before performing simulation. The extraction should be accomplished by the users thus allowing data to be reorganized by event orderings, e.g., time, task, location, operator. For example, it may be necessary to provide a time-line analysis of the data before performing a simulation (see Appendix XII). Data reorganization, based on some type of event ordering, can enable users to determine the necessity for providing additional data before beginning a simulation process. Research has shown that although time-lining is not simulation, it is a necessary starting point in the development of a set of simulation programs. This philosophy is not necessarily valid if a variety of simulation processes are to be used to solve human factors problems in aerospace system development. However, if, as has been indicated, one simulation language and one set of simulation processes are developed to serve the general needs, then it is a very valid and necessary function that aids in the development of this latter capability. When the contents of the data pool have been expanded to include all of the input requirements for the spectrum of simulation processing techniques necessary, the event ordering formatting capabilities will no longer be required. The user can then retrieve the data from the data pool and input these data directly by a calling program which automatically inputs the identified data in simulation processing.

Under the provision that each incremental step in the development of the simulation techniques should result in potential user benefits, the techniques initially employed should be in line with user needs and requirements. However, the initial simulation capabilities should also be considered in terms of other development efforts taking place in the PSES program, such as the data pool organization, content, and vocabulary (see Sections V and VI).

The output of a simulation run should be in a format compatible with the user requirements. D. A. Wilson (1967), of the U. S. Naval Personnel Research Activity, San Diego, California, has developed a scheme for automating Operational Sequence Diagrams (OSD). The OSD is a specialized form of task analysis output developed by the U. S. Navy (see Appendix XII). This method, with some minor modifications, can be programmed as a fixed format output of a simulation run for PSES. Thus, the PSES user would have the option of requesting that the results of his simulation be output in either a fixed format or a user-specified format by applying the COMPOSE program of TDMS (see Section III).

SUMMARY

The research was involved with the feasibility of developing an overall PSES analytic and simulation concept that would meet the requirements established for an operational data handling system. TRACE III, a set of analysis programs developed by SDC, was chosen for investigation to determine whether it would achieve the concepts postulated and operate within the constraints of the PSES. By providing users with a capability to operate TRACE III in the PSES environment, user feedback can be used to determine whether this tool should be integrated into the PSES.

The methodology for developing a simulation capability for the PSES was investigated. A concept for developing simulation within the PSES environment was postulated and the initial steps specified. An open-end approach was recommended as the means to attain the initial goal because it affords a flexible, economical, and expeditious means of simulation development.

These techniques are intended to enable successful research into man-machine problems by allowing users to interpret various configurations of man-machine interactions.

APPENDIX I

SYSTEM DATA SOURCE FORMATS

This appendix contains sample system data source formats used in generating the experimental data pool for the PSES. These formats are:

- ALCC - Time-Line
  Task Information Summary & Task Analysis Work Sheet

- C-5A - Task Analysis Work Sheet
  Requirements Allocation Sheet (RAS)

Formats not included in the appendix are:

- Link analysis (ALCC) a standard presentation of link analysis configuration

- Drawings (ALCC) equipment sketches from QQPRI, engineering sketches showing approximate locations of equipment

  (C-5A) aircraft sketches showing location of work

  (Saturn) configuration sketches showing station numbers and locations of entrance hatches

- Other engineering data
  (ALCC) lists of checkout tapes and informal engineering data

  (C-5A) preliminary estimates of operations and maintenance tasks

  (Saturn) Systems engineering Data Quarterly Reports, Maintenance Analysis and Sequence of [illegible] Documentation

  Equipment Maintenance [illegible] Maintenance Requirements Analysis Form, Time-Line Analysis

- QQPRI - Standard QQPRI Formats (ALCC and C-5A)

BSD Exhibit 65-14
13 May 1965

1. Task
2. Date
3. Function 1st Level
4. Function 2nd Level
5. Job Operation
6. Contractor
7. Activity Level
8. Location
9. Type
10. Frequency
11. Performance Requirements
12. Personnel Requirements
13. Number
14. Time
15. Elapsed Time
16. Total Time
17. [illegible]
18. [illegible]
19. [illegible]
20. [illegible]
21. [illegible]
22. Training Type
23. [illegible]
24. [illegible]
25. [illegible]
26. [illegible]
27. [illegible]
28. [illegible]
29. [illegible]
30. [illegible]

TASK ANALYSIS WORK SHEET

1. DATE:

2. NARRATIVE TASK DESCRIPTION:

PERFORMANCE FACTORS CHECKLIST

FACTORS	COMMENTS

Figure 20. TASK ANALYSIS WORK SHEET

3. MEASUREMENT TECHNIQUES:

( ) Observation
( ) Instrumentation
( ) Questionnaire
( ) Interview
( ) Paper and pencil test
( ) Check of records and logs
( ) Other

4. PROBABLY ERROR FACTOR:

( ) Unlikely
( ) High (see Comment)

5. CONSEQUENCE OF DEVIATIONS:

6. SPECIAL HANDLING:

Care:

( ) Little
( ) Considerable (see Comment)
( ) Moderate

Type:

( ) Manual
( ) Vehicular
( ) Crane
( ) Jack

7. SAFETY PRECAUTIONS:

Sources of Special Danger:

( ) None
( ) Mechanical
( ) Electrical
( ) Explosive

Figure 20 (Continued)

7. SAFETY PRECAUTIONS (Cont)

( ) Volatile Fuels
( ) Toxic Substances
( ) Pneumatic
( ) Hydraulic
( ) Temperature
( ) Fire

Preparations:

( ) Clear Area
( ) Protective equipment or clothing
( ) Emergency Standby (personnel and equipment)
( ) Other warning signs (see Comments)

8. MANIPULATING CONTROLS:

Type:

( ) None
( ) Hand Valves
( ) Push Buttons
( ) Control Auditory Feed Back
( ) Toggle switches
( ) Selector Switches

Actuation Error Probability:

( ) Unlikely
( ) Certain (see Comment)
( ) Possible

9. NATURE OF PROCEDURE:

( ) Fixed
( ) Variable
    ( ) Alternatives specified in procedures
    ( ) Alternatives selected by the individual
( ) Motor Skills
( ) System Analysis
( ) Circuit Analysis

10. SPECIAL CLOTHING USED:

Figure 20 (Continued)

11. TECHNICAL PUBLICATION COVERAGE REQUIREMENTS

( ) Equipment Functional Description
( ) Data Flow Diagram
( ) Schematics
( ) Drawing
( ) Numerical Data
( ) Step-by-Step Procedure
( ) Other ______________________

Figure 20 (Continued)

ALCC TIME LINE SHEE

1.0 ATTAIN FLIGHT READINESS

REF.	NUMBER	FUNCTION	LOC.
1.2	1.1	Turn On Power	
	1.1.1	Go to Circuit Breaker installation - ALCC panel.	CCCBP
	1.1.2	Verify all circuit breakers are closed.	CCCBP
	1.1.3	Go to ALCC POWER SUPPLY Unit	ER2
	1.1.4	Throw POWER switch to ON	ER2
	1.1.5	Go to Code Retaining Power Unit	BATT
	1.1.6	Throw Code Retaining Power Unit ON/OFF switch to ON position	BATT
	1.1.7	Verify Code Retaining Power Unit display is ON	BATT
	1.1.8	Return to STA 1	1-LP
	1.1.9	Confirm POWER ON display is ON	1-LP
	1.2	Perform Lamp Tests	
	1.2.1	Rotate 494L and STA 2 Lamp test thumbwheels to zero	1-4L/2
	1.2.2	Confirm Ø's in multiple-legend lamps (The flight indicators will be sequenced A thru J and K thru T, respectively)	1-4L/2
	1.2.3-20	(Repeat .1 & .2 for 1's thru 9's)	1-4L/2
	1.2.21	Rotate lamp test thumbwheels to ALL	1-4L/2
	1.2.22	Confirm all single legend lamps illuminated	1-4L/2
	1.2.23	Rotate lamp test thumbwheels to OFF	1-4L/2
	1.2.24	Confirm all lamps are OFF	1-4L/2
	1.2.25	Depress STA 1 Launch Control panel LAMP-TEST button	1-LP
	1.2.26	Confirm all lamps illuminated	1-LP
	1.2.27	Release lamp test button	1-LP
	1.2.28	Confirm all lamps are OFF	1-LP
	1.2.29-52	Repeat procedures .1-.24 for DATA PROCESSOR panel lamps	DP
	1.3	Load Exercise Tape	
	1.3.1	Unlock tape reader door.	ER2
	1.3.2	Insert tape reel and adjust	ER2
	1.3.3	Close door & attach two padlocks	ER2
	1.3.4	Go to STA 1, Launch Panel	1-LP
	1.3.5	Depress & release FILL button	1-LP
	1.3.6 *	Receive status; IN PROCESS displ. ON	1-LP
	1.3.7	Receive status; IN PROCESS display OFF, COMPLETE display ON	1-LP
	1.3.8	Depress & release REWIND button	1-LP
	1.3.9	Receive status; IN PROCESS displ. ON	1-LP
	1.3.10	Receive status; IN PROCESS display OFF, COMPLETE display ON	1-LP
	1.3.11	Depress & release MASTER RESET button, COMPLETE display OFF	1-LP
	1.3.12	Report to Maintenance & Operations	LP

* NOTE: Fault light will be "ON" during this procedure.

1 Dependent upon nominal speeds of 31"/sec, assuming 300 feet of tape.

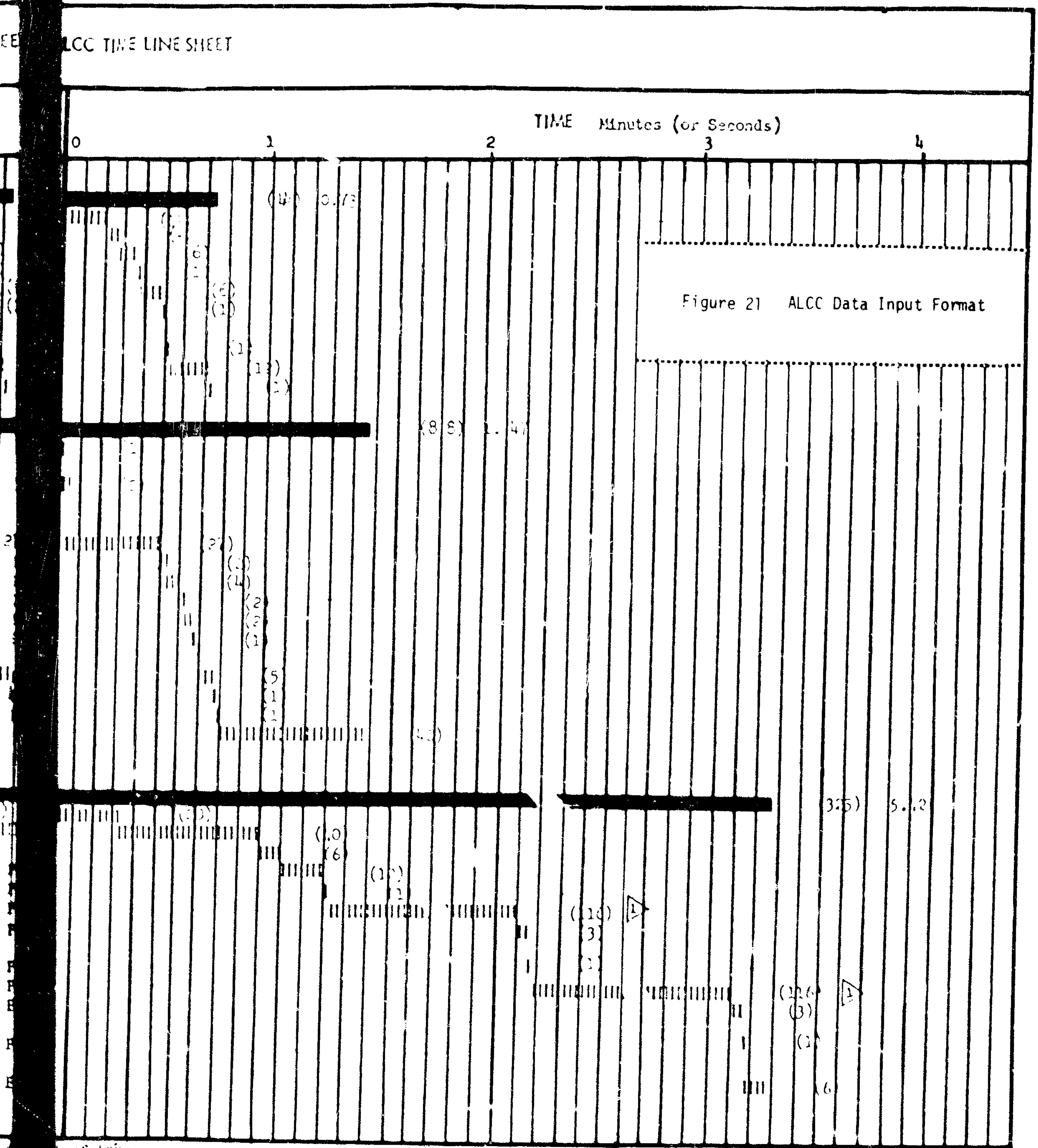

Figure 21 ALCC Data Input Format

of tape.

REQUIREMENTS ALLOCATION SHEET (RAS)
MAINTENANCE

SOURCE FUNCTION NO.	SOURCE DOCUMENT	COMP. CAT.	CEI NO.	EFFECTIVITY
3.0	4ACAH00001	AVE	MA0001A	

CONTROL NO. (NONE (WHEN APPLICABLE): 1135300/0000
TITLE OR NOMENCLATURE: COWL DOOR, LEFT

FUNCTION NO. AND NAME A	PERFORMANCE / DESIGN REQUIREMENTS C	REQUIREMENT ALLOCATION	FACILITY INTERFACE REQUIREMENTS D	COMPONENT IDENTIFICATION E: NOMENCLATURE E1	COMPONENT IDENTIFICATION E: CEI NO. DETAIL SPEC. NO. OR HCM E2	PERSONNEL AND TRAINING COMPONENT REQUIREMENTS F: TASKS F1	TIME REQ. F2	PERFORMANCE REQUIREMENTS F3	TNG & TNG EQUIP. F4	DATA AND TECHNICAL ORDER REQUIREMENTS G
1 REPLACE (AIRCRAFT)	A Remove and replace Left Cowl Door with a like serviceable item.	✓ K P				(1a) Obtain AGE, personnel, and parts, and transport to the work area. After completion of the maintenance task, return AGE, personnel, and defective parts to proper areas.	0.35H (A)	3 Men AFSC (1)43151E (2)43151E 1 - Personnel equipment interface coordination 3 - Plan Work	C III (MTU)	
	B A means of access to the work area will be required. The means will have a capacity for supporting 8 men and their tools, and requiring 80 square feet of support platform to perform the maintenance action at a nominal height of 14.5 feet above ground level, and to provide for opening the nacelle doors. The means will be readily maneuverable and transportable. The raising and lowering will be accomplished in approximately 2 minutes.	✓ K	Storage area for maintenance platform. Refer to VIZ Document No. 4AZAT00063.	Platform, Maintenance, Aircraft Engine	HM0249A					
	a. Distance from the standing surface to the maximum reach point shall not exceed 52 inches.					(1b) Position AGE at work area. Remove AGE upon completion of maintenance task.	0.10H (B)	3 Men AFSC(1)43151E (2)43151E 1 - Activities/communication coordinated 6 - Motor skills	C III (MTU)	
	b. Work space required per man shall not be less than 9 square feet per work station, plus equipment allowance.					(1c) Position personnel. Remove personnel upon completion of maintenance task.	0.10H (C)	3 Men AFSC(1)43151E (2)43151E 1 - Activities/communication coordinated	C III (MTU)	
	c. Means must support weight of 224 pounds per man, plus equipment weight.									
	d. Force required for adjustment, raising, lowering, or positioning equipment while in a standing position: short duration, 80 pounds per man; sustained effort, 40 pounds per man.					(1d) Gain access by opening nacelle doors. Secure access upon completion of maintenance task.	0.15H (D)	3 Men AFSC(1)43151E (2)43151E 1 - Verbal/visual communication 6 - Motor skills	C III (MTU)	
	C Access to the work area will be required. Access will be adequate to perform the function. Access panel fasteners will be quick disconnect type. The access will have a means to prevent closing during maintenance.	E		AVE		(1e) Attach AGE to cowl door. Remove AGE after placing cowl door on cowl panel truck.	0.17H (E)	3 Men AFSC(1)43151E (2)43151E 1 - Verbal/visual communication	C III (MTU)	

ORIGINATOR & DATE	APPROVAL & DATE	REVISER & DATE	REV. APPROVAL & DATE	CODE IDENT NUMBER		CONTRACT NO.	DOCUMENT NUMBER	PAGE	CHG. LTR
R. GRANDY 4-21-66	5-10-66			98897	LOCKHEED-GEORGIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION MARIETTA, GEORGIA	AF 33 (657) 15053	4DA1135300 SOURCE FUNCTION NO. 3.0	3 of	NC

GL FORM GD 2262A-5

Figure 22 C-5A Data Input Format

C-5A FLIGHT C

REF. LINE NO.	FUNCTION ELEMENT	TASK	PILOT	CO-PILOT	NAVIGATOR	ENGINEER
1	2	3	4	5	6	7	8

REVISION NO.	DATE

Figure 23. C-5A Flight Crew Task Analysis

A

CREW TASK ANALYSIS

R	LOADMASTER	LOCATION																							TOLERANCE HAZARD REMARKS
		CONTROL DISPLAY ACCESS				TASK CHARACTERISTIC				VISION		PERFORMANCE					TIME-BREAKDOWN (SEC)				TIME-BUDGET (HRS-MIN)				
		VISIBLE	READABLE	REACHABLE	MANIPULATABLE	USE FREQUENTLY	DIFFICULTY	CRITICALITY	TRAINING REQ.	EXTERNAL	INTERNAL	LEFT HAND	RIGHT HAND	FEET	AUDIO	VERBAL	TIME LIMITATION		TIME STARTED		TIME COMPLETED		CLOCK TIME		
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33

CONTROL DISPLAY ACCESS CODES	USE FREQUENCY CODES	DIFFICULTY CODES	CRITICALITY CODES	TRAINING CODES	CHART NO:
E=EXCELLENT A=ACCEPTABLE M=MARGINAL U=UNSATISFACTORY	O=ONCE PER FLIGHT R=AS REQUIRED I=INTERMITTENT C=CONTINUOUS	1=NO DIFFICULTY 2=MINOR 3=MODERATE 4=VERY DIFFICULT	1=NO HAZARDS 2=POSSIBLE HAZARDS 3=EXTREME HAZARDS	1=FAMILIARIZATION 2=DETAILED 3=FULLY QUALIFIED	FLIGHT PHASE: DATE:

ABOVE CODES RELATE TO TASK CHARACTERISTICS SUBSECTIONS

APPENDIX II

INPUT DATA CONTENT ANALYSIS

ALCC
C-5A
SATURN

LIST OF ABBREVIATIONS

The following abbreviations are used throughout this Appendix under the heading "Source"

PSES - Pilot Study Experimental System

TAWS - Task Analysis Work Sheets

T-L - Time-Lines

RAS - Requirements Allocation Sheet

QQPRI - Qualitative and Quantitative Personnel Requirements Information

MAA - Maintenance Activities Analysis Sheet

DR - Drawings

LA - Link Analysis

OED - Other Engineering Data

All - All Sources Used

ALCC DATA INPUT DESCRIPTIONS

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
1.0 Object System		ALCC	OED	Source Identification
2.0 Mission Information	2.1 Mission	Launch Minuteman missiles from airborne launch control center	OED	N/A
	2.2 Phase	Preflight operations Airborne operations Postflight operations	T-L	Mission Phase
	2.3 Segment	Obtain operational readiness Preattack operations Postflight operations	T-L	Mission Segment
3.0 Hardware Information	3.1 System	Identifiers of system level hardware, such as aircraft, ALCC, 494L, SAC/LCF	TAWS	Hardware Information
	3.2 Subsystem	Subsystem level identifiers, such as aircraft power supply, ALCC station 7, ALCC commo	TAWS	
	3.3 Components	Component level identifiers, such as power panel (ALCC) address panel, (Aircraft), data processing panel	TAWS	
	3.4 Part	Parts of components, assemblies, or subassemblies, such as toggle switch, thumbwheels headset and microphone		
4.0 Performance Description	4.1 Level	A descriptor that specifies the detail --ranging from gross to detailed-- of the activity being performed. The levels are: position, job and task.	TAWS	Entry Type

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
4.0 Performance Description (continued)	4.2 Description	Performance goal or objective contains the following: <u>Verb</u> The action or behavioral verb that describes the activity performed <u>Object</u> The object noun that describes the locus of the activity <u>Modifiers</u> Various adjectives, adverbs, pronouns, and nouns that are used to further define the object of the activity	TAWS, T-L	Task
	4.3 Procedural Steps	Statements that describe the sequentials steps the operator performs --man/machine interactions--to accomplish the performance objective--form of presentation will be: verb, object, modifiers	TAWS, T-L, QQPRI, DR, L-A, OED	Performance Descriptors
5.0 Performance Characteristics	5.1 Location	Statements regarding the location of the activity, e.g., aircraft power supply panel, ALCC Station 1 This category may often be identical to category 3--System Information	TAWS, DR	Location
	5.2 Frequency	Statements regarding the number of times the activity is required per operation, e.g., once per flight, unscheduled (will occur as required by the mission), three per operation	T-L, TAWS	Task Frequency

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
5.0 Performance Characteristics (continued)	5.3 Difficulty	An entry from one of the following codes: G--equipment design makes task performance difficult P--skill or knowledge required makes personnel selection and training difficult, and a high probability of performance failure is anticipated X--other	TAWS	Difficulty
	5.4 Criticality	An entry from one of the following codes: A--performance failure will cause an abort resulting in equipment damage or personnel injury C--performance failure will allow operation to be carried out but not within planned limits D--performance failure will allow operation to be carried out but delayed beyond operational tolerances E--performance failure will not affect successful operation S--task is applicable to supporting activities and will not materially affect operations	TAWS	Criticality
	5.5 Hazards	Statements regarding hazardous conditions in equipment or operating environment. One or more of the following entries may be used:	TAWS, OED	Hazards

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
5.0 Performance Characteristics (continued)	5.5 Hazards	mechanical, electric, pneumatic, hydraulic, and explosive		
	5.6 Training Requirements	Statements regarding the training necessary for operating and maintenance personnel	TAWS, QQPRI	Training Requirements
	5.7 Special Tools Equipment	Statements regarding the necessity and the type of special tools and equipment required for successful performance of an activity	TAWS, QQPRI	Special Tools, Equipment
6.0 Hardware Characteristics	6.1 Equipment Status	Statements regarding the developmental state of the equipment including the following: mock-up, breadboard, prototype, and production	OED	Hardware Information
7.0 Personnel Description	7.1 Type	A descriptive name--job title--of the type of operator required for the activity, and if applicable, the AFSC or other descriptors Additional job titles and AFSC's will be added for any helper personnel required		Personnel name and AFSC
	7.2 Number	The total number of operators and helpers required for the accomplishment of an activity	TAWS QQPRI OED	Personnel Number
	7.3 Special Skills/ Knowledge Required	Statements regarding special skills and knowledge required of the operator	TAWS	Remarks or Training Requirements

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
7.0 Personnel Description (continued)	7.4 New Skills/ Knowledge	Statements that describe any skills and knowledge required for the activity that is not presently included in the job description or AFSC	QQPRI OED	Remarks or Training Requirements
8.0 Time Information	8.1 Time	Time required for job or task performance, expressed in minutes	T-L TAWS	Total task time
	8.2 Time Contraints	The accumulation of task element time increments to produce the position time for the mission segment, expressed in minutes	T-L TAWS	Remarks
	8.3 Time Criticality	Values relative to time contraints that may affect successful mission performance, expressed in minutes	T-L TAWS	Remarks
9.0 Remarks		Miscellaneous remarks necessary to explain or supplement information contained in other data elements	All	Remarks
10.0 Source Identifiers	10.1 Author	The name of the person or group responsible for the input	All	
	10.2 Organization	The name of the prime organization submitting the input	All	Source Identification
	10.3 Date	Preparation date of the input	N/A	Entry Date
	10.4 Revision Code	The revision code designated by the contractor or sub-contractor that specifies revisions to data inputs	TAWS	Revision, Revision Date
	10.5 Security/ Proprietary	An entry from the following codes that indicates the security or proprietary status of the input:	All	Source Identification

DATA ELEMENTS	ATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
10.0 Source Identifiers (continued)	10 5 Security/ Propri- etary	T - Top Secret S - Secret C - Confidential U - Unclassified A - Atomic energy data (Restricted Data) P - Proprietary The letter A is used with other codes where applicable, e.g., TA - Top Secret atomic energy data		
	10.6 Type of Per- formance	A descriptor that identifies the type of activity--these are: operational, maintenance, routine, continuous, and discrete	TAWS	N/A
	10.7 Refer- ences	The references include: the documents, charts, and flows, used by the analyst in the preparation of his analysis reference to a previous or sub- sequent TEA that is required as a prerequisite for the current TEA	All	Source Identification

C-5A DATA INPUT DESCRIPTIONS

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
1.0 Object System		C-5A		Source Identification
2.0 Mission Information	2.1 Mission	Transports Troops/Cargo	TAWS	N/A
	2.2 Phase	Preflight Operations Flight Operations Flight Maintenance Preventive Maintenance Periodic Phased Inspection Ground Maintenance	TAWS T-L	Mission Phase
	2.3 Segment	Preparations for Engine Startup Activate Engines Taxi Before Line-Up Line-up and Take-off Climb Cruise Descend Approach and Landing MADAR Routine Preflight Maintenance Inspection Postflight/Thruflight Maintenance Inspection Phased Inspection No. 1 Inspect Aft Pressure Inspect Engine Nacelle Inspect Nose Landing Gear Strut Assembly Inspect Leading Edge Panel No. 3 Tow Air Vehicle	TAWS T-L	Mission Segment
3.0 Hardware Information	3.1 System	System level identifiers, such as: Aircraft Propulsion System Aircraft Navigation Systems Ground Support Equipment	TAWS RAS	Hardware Information

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
3.0 Hardware Information (continued)	3.2 Subsystem	Subsystem level identifiers, such as: Propulsion Hydraulic Subsystem Propulsion GE 1/6 Turbofan Engines Control Hydraulic Subsystem Main Landing Gear	TAWS RAS	Hardware Information
	3.3 Components	Component level identifiers, such as: Aft Cargo Door LG Nose Wheel Shock Strut Wheel No. 3 of LH bogey, Main Landing Gear Seat, crew member	TAWS RAS	
	3.4 Parts	Statements regarding the various parts used during the performance of an activity, e.g., Tires 1600 x 40 for Main Landing Gear Toggle Switch - FSN 80645 x P76 Seat cushion - FSN AN/QPR-776 Ball, Throttle, Master - LAC 837654 Upright, Throttle, Master - LAC 796405 Pin, Throttle Linkage, Master - LAC 4856	TAWS RAS	
4.0 Performance Description	4.1 Level	A word that describes the depth of detail of the activity. The levels are: JOB TASK	TAWS RAS OED	Entry type
	4.2 Procedural Steps	Statements describing the sequential man/machine actions and relationships 1055Z Pilot sets trim tabs .02 seconds	TAWS RAS OED	Performance Descriptors

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
4.0 Performance Description (continued)	4.2 Procedural Steps	10.5Z Copilot reads before take-off checklist for Pilot's compliance		
5.0 Performance Characteristics	5.1 Location	Statements that describe specifically where the personnel are located during the performance of an activity, e.g., Pilot's crew station, mechanic at aft cargo area, truck driver at truck's cab and wench operator at crane controls	TAWS RAS DR	Location
	5.2 Frequency	A coded entry describing: the number of times per task the man/machine action occurs; the number of times per function (F) or mission segment the task or function is performed. The codes are: O = Once per flight R = As required I = Intermittent C = Continuous Maintenance frequency will be determined by the Using Commands' Maintenance Pc icy	TAWS RAS	Task Frequency
	5.3 Criticality	A coded entry expressing the hazards involved. The codes are: 1 = No hazards 2 = Possible hazards 3 = Extreme hazard.	TAWS RAS	Hazards and Performance Criticality
	5.4 Difficulty	A coded entry expressing the personnel skill needed to perform the task. It is indicative of the perceptual,	TAWS RAS	Performance Difficulty

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
5.0 Performance Characteristics (continued)	5.4 Difficulty	judgmental, and motor skill demands made on human performance. The codes are: 1 = No difficulty 2 = Minor difficulty 3 = Moderate difficulty 4 = Very difficult		
	5.5 Special Tools	Statements indicating the necessity for, type of, and part number of special tools (not part of an ordinary mechanics tool kit) or equipment necessary to successfully complete the task or function	TAWS RAS OED	Special Tools/ Equipment
	5.6 Accessi-bility	Statements relative to equipment accessibility for operability or maintainability	TAWS RAS	Equipment Maintainability & Equipment Reacha-bility
	5.7 Visi-bility	Statements relative to equipment visibility or legibility for operability or maintainability	TAWS RAS	Equipment Readability
	5.8 Manipu-lability	Statements relative to equipment manipulability for operability or maintainability	TAWS RAS	Equipment Manipulability
6.0 Personnel Description	6.1 Type	The standard Air Force Officer and Enlisted Classification of specialty descriptions and codes	TAWS QQPRI RAS	Personnel name and AFSC
	6.2 Number	A value signifying the total number of AFSC's required to accomplish the task. NOTE: Crew tasks or functions are sequentially timed, beginning with	TAWS RAS	Personnel Number

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
6.0 Personnel Description (continued)	6.2 Number	the aircraft commander's call for a mission		
7.0 Time Information	7.1 Time Limitation	A specific time expressed in hours and minutes which signifies the maximum time allowable for the successful completion of the task or function and/or a specific time during which the task or function must begin	T-L TAWS RAS	Remarks
	7.2 Time Started	The specific time, in hours and minutes, at which the task or function begins	T-L TAWS RAS	Start Time
	7.3 Time Completed	The specific time, in hours and minutes, at which the task or function is completed	T-L TAWS RAS	Stop Time
	7.4 Clock Time	A calculated value expressed in hours and minutes obtained by subtracting Time Started from Time Completed. This value also represents the total task time for a time-line analysis	T-L TAWS RAS	Total Task Time
8.0 Remarks	8.1 Remarks	Miscellaneous comments and/or remarks necessary to amplify or explain any material contained in the other data elements or items	All	Remarks
	8.2 Pre-Conditions	Concise statements of conditions that must exist and upon which the start or successful completion of the task or function are dependent	All	Remarks

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
9.0 Source Identifiers	9.1 Author	The name of the author of the source document	All	Source Identification
	9.2 Organization	The name of the organization for which the analysis or document was prepared	All	Source Identification
	9.3 Date	The date of preparation of each analysis or of the complete document when each analysis sheet is not dated, or blanks	All	Revision Data
	9.4 Revision	The revision code designated by the originator for specifying revisions to analysis or entire documents		Revision
	9.5 Security	A coded designator of the security classification of the document or specific analysis and/or a coded designator that the analysis or document contains company proprietary information. The codes are: T = Top Secret S = Secret C = Confidential U = Unclassified A = Atomic Energy Data (Restricted Data) P = Proprietary Data NOTE: The designator "A" may also be used with other security designators, e.g., TA = Top Secret Atomic Energy Data		Source Identification
	9.6 Reference	A list of the references used by the analyst in the preparation of the analysis	All	Source Identification

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
9.0 Source Identifiers (continued)	9.7 Preparation Date	The date on which the data extraction process was completed	N/A	Entry Date

SV-IC DATA INPUT DESCRIPTIONS

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
1.0 Object System		Saturn V		
2.0 Mission Information	2.1 Mission	Statements describing the operational mission of the object systems; Assembly, Checkout, and Launch Vehicle	MAA RAD CED	N/A
	2.2 Phase	Vehicle Systems Analysis	RAS MAA T-L	Mission Phase
	2.3 Segment	Vehicle Maintenance Analysis for SA-501 Pad Fueled	RAS MAA T-L	Mission Segment
3.0 Hardware Information	3.1 Subsystem	Subsystem level identifiers, such as: Hydraulic System LOX System SV-IC Fuel System Vehicle Propulsion	MAA RAS	Hardware Information
	3.2 Components	Component level identifiers, such as: Signal Conditioner Valve Assembly Power Transfer Switch Tape Recorder LOX Pre-valve		
	3.3 Parts	Statements regarding the various parts of components required in the activity, e.g., Lockwasher Tubing Coaxial Switch Fuel Pre-valve Position Indicator		

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
4.0 Performance Description	4.1 Level	A word that specifies the level of activity. The levels are: JOB TASK	RAS MAA	Function
	4.2 Elements	Statements that describe the sequential elements		TASK and Performance Description
5.0 Performance Characteristics	5.1 Location	The location of the performance activity. Letter Codes A. KSC B. MSFC C. MTO D. SACTO E. CONTRACTOR FACILITY	RAS MAA	Location
	5.2 Frequency	The Maintenance Activity Rate expresses the probability of occurrence of a maintenance activity. It is expressed in dimensions of occurrence of 1000 operating hours.	T-L MAA RAS	Task Frequency
	5.3 Criticality	Entries indicate the effect of non-performance or improper performance of each maintenance task. The following code letters are used as appropriate: A - little or no effect B - some degradation of equipment, no measurable effect upon mission success C - mission success would be compromised to an unacceptable degree	MAA RAS	Criticality

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
5.0 Performance Characteristics (continued)	5.4 Special Tools & Equipment	Statements indicating the necessity for and type of tools or equipment required to successfully perform the task	MAA RAS	Special Tools & Equipment
6.0 Personnel Description	6.1 Type	A three digit code is used to identify type of personnel. The first digit indicates the field with which the man is familiar, such as electrical or mechanical. The second digit indicates the area in which the man specializes, such as machinist or welder. The third digit indicates the level of proficiency within the specialty area, such as master, journeyman, or helper. As the required level of job skill increases, so does the third digit. The lowest proficiency level capable of performing the described task is assigned.	MAA RAS OED	Personnel Names Personnel Code
	6.2 Difficulty	This entry indicates the personnel skill level needed to perform the task described. It is indicative of the perceptual, judgmental, and motor skill demands made on human performance. A three-digit code is used to indicate those demands. The first digit represents the perceptual demand. The second digit represents the judgmental demand, and the third digit the motor skill required. The numbers 1 through 3 are used to indicate the level of demand. The greater the demand, the higher the code number assigned.	MAA RAS OED	Personnel Code

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
6.0 Personnel Description (continued)	6.3 Number	A value signifying the total number of personnel required to accomplish the task	MAA RAS	Personnel Number
7.0 Time Information	7.1 Duration	This entry is the elapsed time for repair or service. It is expressed in hundredths of an hour.	MAA RAS T-L OED	Function Start Time, Function Checkout Time, Function Time Budget
8.0 Remarks	8.1 Remarks	Miscellaneous comments and/or remarks necessary to amplify or explain any material contained in the other data elements	All	Remarks
	8.2 Pre-Condition	Conditions (Operational Technical Requirements) that must exist prior to beginning the maintenance loop.	RAS MAA T-L	Remarks
9.0 Source Identifiers	9.1 Author	Author - the name of the author of the analysis or documents	All	Source Identification
	9.2 Organization	Organization - the name of the organization responsible for the preparation of the analysis or document (usually the Contractor or Subcontractor)	All	
	9.3 Date	Date - Date of preparation of each analysis or of the complete document whichever is later	All	Revision Date
	9.4 Revision	Revision - the revision code designated by the Contractor or Subcontractor for specifying revisions to analysis or entire documents	All	Revision

DATA ELEMENTS	DATA ITEMS	DEFINITION CONTENT	SOURCE	LUCID ELEMENTS
9.0 Source Identifiers (continued)	9.5 Security	Security - A designator of the security classification of the analysis or document and/or a designator of the fact that the analysis or document contains proprietary information. The code utilized will be: T = Top Secret S = Secret C = Confidential U = Unclassified A = Atomic Energy Data (Restricted Data) P = Proprietary Data NOTE: The designator "A" is to be used with other data where it is applicable, e.g., TA = Top Secret Atomic Energy Data UA = Unclassified Atomic Energy Data PA = Proprietary Atomic Energy Data		
	9.6 Reference	References - The listing of the references used by the analyst in the preparation of his analysis	All	Source Identification

APPENDIX III

DEFINITION OF DATA ELEMENTS (LUCID)

DEFINITION OF DATA ELEMENTS (LUCID)

The following is an alphabetized list of all the data elements contained in the LUCID data bases. The list contains the definition of each element and identifies the data base with which the element is associated.

AFSC (ALCC, C-5A) - contains the Air Force Specialty Code of the individuals required to perform tasks. If more than one type of person is required to perform a given task, AFSC contains multiple codes. The information is alphanumeric in composition and contains a maximum of 6 characters, e.g., 1416, 43151E. The AFSC is not accessible by its individual parts, e.g., shredout, skill level, career field.

CRITICALITY (ALCC, SATURN) - contains the degree of criticality associated with the overall performance of a task. For SATURN, the information is presented in descriptive phrases containing a maximum of approximately 150 characters. For ALCC, the information is presented in the following codes.

Code	Equivalent Degree of Criticality
A	Performance failure will cause an abort resulting in equipment damage or personnel injury.
B	Performance failure will cause an abort resulting in equipment damage and no personnel injury
C	Performance failure will allow operation to be carried out but not within planned limits
D	Performance failure will allow operation to be carried out but delayed beyond operational tolerances
E	Performance failure will not affect successful operation
S	Task is applicable to supporting activities and will not materially affect operations

DIFFICULTY (ALCC) - contains the degree of difficulty associated with the overall performance of a task. The information is presented in the following codes.

Code	Equivalent Degree of Difficulty
G	Equipment design makes task performance difficult
P	Skill or knowledge required makes personnel selection and training difficult, and a high probability of performance failure is anticipated.
X	Other

ENTRY DATE (all) - contains the date the information was entered into the data base. The date is presented in the form of three pairs of digits that represent year-month-day. For example, 670321 represents March, 21, 1967.

ENTRY NUMBER (all) - contains a unique numerical identifier assigned to each task as it is entered into a data base. The identifiers are assigned sequentially within each system and contain from 1 to 3 digits.

ENTRY TAPE (all) - designates whether the data base entry describes a task as originally entered into the data base, or whether the entry has been subsequently updated in response to modifications to the task. If the task has not been updated, the element contains the value NEW ENTRY in ALCC and C-5A and the value NEW TASK or NEW FUNCTION in SATURN. If updated, the element contains a short description of the modification.

EQUIPMENT MANIPULABILITY (C-5A) - indicates how well an individual can manipulate the equipment utilized in performance of a task. The information is presented in the following codes:

Code	Equivalent Manipulability
E	Excellent
A	Acceptable
M	Marginal
U	Unacceptable

EQUIPMENT REACHABILITY (C-5A) - indicates how well an individual can reach the equipment utilized in performance of a task. The information is presented in the following codes:

Code	Equivalent Reachability
E	Excellent
A	Acceptable
M	Marginal
U	Unacceptable

EQUIPMENT READABILITY (C-5A) - indicates how well an individual can read a display surface, gauge, etc., utilized in performance of the task. The information is presented in the following codes:

Code	Equivalent Readability
E	Excellent
A	Acceptable
M	Marginal
U	Unacceptable

EQUIPMENT VISIBILITY (C-5A) - indicates how well an individual can see an item of hardware that is required for the performance of a task. The information is presented in the following codes:

Code	Equivalent Visibility
E	Excellent
A	Acceptable
M	Marginal
U	Unacceptable

FUNCTION (all) - indicates that portion of a mission profile that is performed by a related group of tasks. The information is alphanumeric in composition and contains a maximum of 72 characters.

FUNCTION CHECKOUT TIME (SATURN) - contains the total time, expressed in minutes, to perform the automated operation as described in the function.

FUNCTION DESCRIPTORS (SATURN) - contains the names and sequence of tasks which are performed if a failure is detected during the automated checkout.

FUNCTION START TIME (SATURN) - contains the time, in minutes, at which a function begins. Time begins with a large negative number and proceeds to zero.

FUNCTION TIME BUDGET (SATURN) - contains two values identifying increments or decrements of time, in minutes, by which the start and stop times of a task may be altered without affecting the performance of a task. The information is alphanumeric in composition. Example: START T-167 HR, END T-156 HR 30 MIN.

HARDWARE INFORMATION (all)- contains the names or designators of the hardware associated with a specific task. The information is alphanumeric in composition and contains a maximum of 72 characters for each item of hardware.

HAZARDS (all) - contains information regarding the risk associated with performing a given task. The information is alphanumeric in composition and contains a maximum of 72 characters per value.

LOCATION (all) - describes the physical place associated with the performance of a task. Locations range from specific crew work stations for operational tasks to field maintenance facilities for maintenance tasks. The information is alphanumeric in composition and contains a maximum of 72 characters.

MISSION PHASE (all) - contains the broadest level of mission profile information of a task. It is alphanumeric in composition and contains a maximum of 72 characters. Typical values are "preflight," "airborne," and "post-flight" operations.

MISSION SEGMENT (all) - contains a breakdown of the mission phase in which a task is performed. The information is alphanumeric in composition and contains a maximum of 72 characters. Typical values (for the mission phase "airborne operations") include "climb," "cruise," and"descend".

PERFORMANCE CRITICALITY (C-5A) - contains, for each individual involved in the performance of a task, the degree of criticality associated with its performance. The information is presented in the following codes:

Code	Equivalent Criticality
1	No Hazard
2	Possible Hazard
3	Extreme Hazard

PERFORMANCE DESCRIPTORS (all) - contain the individual man/machine procedural steps required of individuals in order to perform a specific task. Procedural steps are the smallest set of perceptions, decisions, and responses which the human must perform in conducting a task. Included with each procedural step is the AFSC or NASA designator of the individual or individuals performing the operation as well as the total time required to perform the procedural step. The information is alphanumeric in composition and is generally quite lengthy.

PERFORMANCE DIFFICULTY (C-5A) - contains, for each individual involved in the performance of a task, the degree of difficulty associated with the performance.

The information is presented in the following codes:

Code	Equivalent Difficulty
1	No difficulty
2	Minor
3	Moderate
4	Very

PERFORMANCE FREQUENCY (C-5A) - indicates, by code, how often each individual involved in the task performs his assigned duties.

Code	Equivalent Frequency
0	Once per flight
A	As required
I	Intermittent
C	Continuous

PERSONNEL NAME (all) - contains the official title, e.g., pilot, radio repairman, of personnel involved in the performance of tasks. A name exists for each AFSC or personnel code identified for a task

PERSONNEL NUMBER (all) - contains one or more numeric values representing the number of each personnel type required to perform a task.

PERSONNEL TIME (all) - contains one more times, each associated with a particular personnel type and identifies the amount of time, in minutes, spent in the performance of a task by each of the personnel types involved in the task.

REMARKS (all) - contains the revision code associated with the last revision of the task. The information is expressed by a single letter, or, if no revision has occurred, the word NONE.

REVISION (all) - contains the revision code associated with the last revision of the task. The information is expressed by a single letter, or, if no revision has occurred, the word NONE.

SAFETY PRECAUTIONS (all) - contains statements regarding precautions to be taken during the performance of a task. The information contains a maximum of 255 characters.

SOURCE IDENTIFICATION (all) - contains the author, document references, originating organization, security classification and date associated with the analysis of a task.

SPECIAL SKILLS (C-5A) - contains statements identifying the visual, verbal, preceptual, motor, judgmental capabilities and the knowledge of theory required by individuals to properly perform a task.

SPECIAL TOOLS/EQUIPMENT (all) - contains the items of equipment required to perform a task. Each item contains a maximum of 72 characters.

START TIME (C-5A) - contains the time, in minutes, at which a task begins. For C-5A, time is calculated chronologically from the start of the preflight phase, beginning at time zero and continuing until the end of the post-flight phase.

STOP TIME (C-5A) - contains the stop time, in minutes, associated with the performance of a task. The time is referenced chronologically from the start of the preflight phase, which is identified as time zero.

TASK (all) - contains the name of the task being described. The task is the basic performance unit of a mission profile. It is a grouping of procedural steps that specify the individual human actions required to perform the task. The task name contains a maximum of 72 characters with only minor exceptions.

TASK FREQUENCY (all) - describes how often a task is performed. The information is alphanumeric and contains values such as "once per flight", "as required", and "twice per mission."

TOTAL TASK TIME (all) - contains the total time, in minutes, required to perform a task.

TRAINING REQUIREMENTS (ALCC, C-5A) - identifies those specific training requirements necessary for each personnel type involved in the performance of a task.

For ALCC, requirements are presented in the form of descriptive phrases. For C-5A, the following codes are used:

Code	Equivalent Training Requirement
1	Familiarization only
2	Detailed knowledge
3	Fully qualified

APPENDIX IV

INPUT DATA FORM

Index No.

1) Object System:	2) Date/Revision: 3) Security Classification
4) Orignating Organization	5) Author/Document:
6) Reference:	7) Type of Performance
8) Function/Task, Name/Number:	9) Mission Information

10) System Information

11) Hardware Characteristics:

12) Remarks (Indicate Specific Referent Block or Subject):

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Index No.

13) Performance Description

14) Performance Characteristics

15) Personnel Description

16) Time Information

Form
AMRL-0 89
Aug 66

APPENDIX V

DATA ELEMENTS (LUCID)

DATA ELEMENTS LISTS

The following four lists contain the elements of data used to define the ALCC, C-5A, SATURN, and INDEX data bases, respectively. Definitions for each of the categories are contained in Appendix III .

ALCC DATA BASE

ENTRY NUMBER
ENTRY TYPE
ENTRY DATE
SOURCE IDENTIFICATION
REVISION
REVISION DATE
REMARKS
MISSION PHASE
MISSION SEGMENT
FUNCTION
TASK
PERFORMANCE DESCRIPTORS
LOCATION
HARDWARE INFORMATION
SPECIAL TOOLS/EQUIPMENT
TASK FREQUENCY
HAZARDS
SAFETY PRECAUTIONS
PERFORMANCE TYPE
TOTAL TASK TIME
* PERSONNEL NAME
* AFSC
* PERSONNEL NUMBER
* PERSONNEL TIME
DIFFICULTY
CRITICALITY
TRAINING REQUIREMENTS

---

* Each of these elements contains multiple values that share a correspondence with each other across the elements, e.g., the first values for PERSONNEL NAME and AFSC are directly related, as are the second values, and so forth.

A DATA PAGE

ENTRY NUMBER
ENTRY TYPE
ENTRY DATE
SOURCE IDENTIFICATION
REVISION
REVISION DATE
REMARKS
MISSION PHASE
MISSION SEGMENT
FUNCTION
TASK
PERFORMANCE DESCRIPTORS
LOCATION
HARDWARE INFORMATION
SPECIAL TOOLS/EQUIPMENT
TASK FREQUENCY
HAZARDS
SAFETY PRECAUTIONS
PERFORMANCE TYPE
TOTAL TASK TIME
* PERSONNEL NAME
* AFSC
* PERSONNEL NUMBER
* PERSONNEL TIME
* PERFORMANCE DIFFICULTY
* PERFORMANCE CRITICALITY
* TRAINING REQUIREMENTS
* PERFORMANCE FREQUENCY
* EQUIPMENT VISIBILITY
* EQUIPMENT READABILITY
* EQUIPMENT READABILITY
* EQUIPMENT REACHABILITY
* EQUIPMENT MANIPULABILITY
SPECIAL SKILLS
START TIME
STOP TIME

---

* Each of these elements contains multiple values that share a correspondence with each other across the elements, e.g., the first values for PERSONNEL NAME and AFSC are directly related, as are the second values, and so forth.

ACTION DATA AREA

ENTRY NUMBER
ENTRY TYPE
ENTRY DATE
SOURCE IDENTIFICATION
REVISION
REVISION DATE
REMARKS
MISSION PHASE
MISSION SEGMENT
FUNCTION
TASK
PERFORMANCE DESCRIPTORS
LOCATION
HARDWARE INFORMATION
SPECIAL TOOLS/EQUIPMENT
TASK FREQUENCY
HAZARDS
SAFETY PRECAUTIONS
PERFORMANCE TYPE
TOTAL TASK TIME
* PERSONNEL NAME
* PERSONNEL CODE
* PERSONNEL NUMBER
CRITICALITY
FUNCTION DESCRIPTORS
FUNCTION START TIME
FUNCTION CHECKOUT TIME
FUNCTION TIME BUDGET

---

* Each of these elements contains multiple values that share a correspondence with each other across the elements, e.g., the first values for PERSONNEL NAME and PERSONNEL CODE are directly related, as are the second values, and so forth.

[illegible]

The following is a list of the data categories contained in the Index data base, INDEX. Use of the data base is described in Section III, page [illegible]

SYSTEM
MISSION PHASE
MISSION SEGMENT
FUNCTION
SYSTEM BREAKOUT
* PERSONNEL CODE
* PERSONNEL TYPE
HARDWARE

Definitions for the categories are the same as those defined in Appendix III , except for the following, which are unique to INDEX:

SYSTEM contains the names of all systems for which data bases exist in the data pool.

SYSTEM BREAKOUT contains a hierarchical list of all mission phase, mission segment, and function values. It is used to provide detailed insight into the nature of a particular system data base.

PERSONNEL CODE contains either the AFSC or NASA designated personnel codes

---

* Each of these elements contains multiple values that share a correspondence with each other across the elements, e.g., the first values for PERSONNEL CODE and PERSONNEL TYPE are directly related, as are the second values, and so forth.

APPENDIX VI

GUIDELINES FOR DATA EXTRACTION

ALCC
C-5A
Saturn

GUIDELINES FOR DATA EXTRACTION (ALCC)

General

The fundamental task to be performed is to extract the data from the source materials and record them on the forms provided. The information should be recorded exactly as it appears in the source material. Few judgments will be necessary on your part to complete the sixteen items on the form.

Specific Instructions

Number forms sequentially beginning with 001. Place the number in space labeled Index Number.

Block 1 - Will always be "ALCC-AVE"
Block 2 - Will always be 1/25/66
Block 3 - Write Unclassified
Block 4 - Will always be "Boeing"
Block 5 - Document title will always be "ALCC Operational Task Analysis and Timeliness"
Block 6 - Data are found on line #30 of the Task Information Summary (TIS)
Block 7 - Data are found on line #11 of TIS
Block 8 - Data are found on line # 1 of TIS
Block 9 - Data are found on lines #3 and 4 of TIS
Block 10- Extract data from lines #18 and 19 of TIS

a. Copy each different coded equipment designator from the time-line of the corresponding task time-line. (Examples of coded designators are circles in red on page 2 of Section 2 (Time-lines).)

b. Each TIS has a corresponding TAWS (Task Analysis Work Sheet). this TAWS is found on the page following the TIS. Extract from paragraph 8 of the TAWS, any controls or equipment that appears with a check (✓) mark. Supplemental equipment information may appear in paragraph 2 of TAWS; if so, include this information.

NOTE : Tools are not equipment. We are concerned here with equipment components and subassemblies We are not concerned with conditions under which they are used. (See Block 16 remarks.) Do not duplicate equipments or controls.

Block 11- Will always be blank
Block 12- Although the section appears early in the form, it should be completed only after all other sections have been completed. (Proceed to Block 13.)

. Miscellaneous comments necessary to explain any of the other items.

b. Specifically - if the paragraph #6 (Special Handling) of TAWS is checked (✓) considerable - record from paragraph # 2 of TAWS, the corresponding comment regarding what that special handling consists of.

c. Record any comments from paragraph #5 of TAWS regarding Consequence of Deviation here.

d. Any other pertinent information which you feel should be called to our attention regarding this "task".

Block 13- Copy each step in sequence from Task Time-line of corresponding task. (Example is shown on page 3 of Section 2, Time-lines.)

NOTE: Do not include time information. It is recorded in another block.

Block 14- a. See line #8 of TIS for location.
b. See line #10 of TIS for frequency.
c. See line #17 of TIS for criticality/difficulty.
d. See line #22 - 25 of TIS for Training Requirements.
e. See paragraph 2 of TAWS for special tools - if none, write none.
f. See paragraph 7 of TAWS for Safety Precautions.

NOTE: For this item, please label the information a - b - c - etc.

Block 15- See line 12 of TIS.
Block 16- See lines 14-15-16 of TIS. Please give time, title, i.e., elapsed time, and numerical value.

At this point, complete Block 12, a - d.

GUIDELINES FOR DATA EXTRACTION C-5A

General

The fundamental task to be performed is to extract the data from source materials and record them on the forms provided. The information recorded should be recorded exactly as it appears in the source materials. Few judgments will be necessary on your part to complete the sixteen items on the form.

Specific Instructions

Number forms sequentially: Maintenance beginning with 001, Operations beginning with 401. Place the number in the block titled "Index Number".

Block 1 - Will always be C-5A
Block 2 - Will be found on the "Requirements Allocation Sheet" (RAS) or the "Crew Task Analysis" sheet as "Originator & Date". If a revision has been made, it will be identified on the "RAS" or the "Analysis".
Block 3 - Will always be Unclassified.
Block 4 - Will always be Lockheed.
Block 5 - Maintenance document title will always be Requirements Allocation Sheet (RAS) and the "Document Number". The author will be found in the lower left of the RAS as "Originator and Date".

Operations document title will always be C-5A Flight Crew Task Analysis.
Block 6 - For maintenance tasks, copy from "Source Document" block.

For operations tasks use, None.
Block 7 - For maintenance, use Preventive Maintenance or Maintenance as indicated by source documentation.

For operations, use Flight Operations - Routine.
Block 8 - For maintenance, (F) use title from the first sheet of a maintenance operation; (T) use descriptor title of operation being performed and repeat title from (F), e.g., (F) Inspect Aft Pressure Door LH (T) Remove Aft Pressure Door LH.

For operations, (F) use title from first entry of "Analysis Sheet" column 4; (T) use title from next indenture of column 4, e.g., (F) Start Engines and Before Take-off; (T) Check Radios.
Block 9 - For maintenance:
Mission - transport personnel/cargo
Phase - ground maintenance
or
phased inspection
Segment - enter specific operation being performed
For operations:
Mission - transport personnel/cargo
Phase - preflight
or
flight
Segment - enter specific operation being performed

Block 10- For (F) accumulate all hardware items used in subsequent tasks.

For (T) and maintenance enter information found in columns E1 and E2 of RAS.

For (T) and operations, enter hardware units from column 9 actually used during the performance.

Block 11- For maintenance, enter None.

For operations, enter code found for each performer under the following categories:

Visible, column 10
Readable, column 11
Reachable, column 12
Manipulatable, column 13

Block 12 -Although the section appears early in the form, it should be completed only after all other sections have been completed. Proceed to Block 13. Block contents will consist of:

Miscellaneous comments necessary to explain any of the other items. (Maintenance; Column C of the RAS).

Record any "Cautions" or "Notes".

Record any pre-function or pre-task conditions that must be accomplished before this event can be started.

For maintenance, enter any data from column G of the RAS.

Record any other information which you feel should be called to attention regarding the task or function.

Block 13- If (F) copy the task titles that are included under this function.

If (T) copy the AFSC, the action(s) performed and the time required for each action.

For (T) maintenance use columns F3, F1, and F2.

For (T) operations enter AFSC as follows:

Pilot	1055Z - column 4
Copilot	1045Z - column 5
Navigator	1535Z - column 6
Flight Engineer	1585 - column 7
Loadmaster	60570 - column 8

Copy man/machine action from appropriate column and enter time.

Block 14- Location - describe location where performance is occurring, Use column 9 on "Analysis sheet" for operations.

For operations:

Enter codes as indicated in the particular column for each performer for the following categories:

Frequency, column 14
Difficulty, column 15
Criticality, column 16
Training Requirements, column 17

NOTE: If more than one value is entered on the source sheet, for a single performer in any of the above categories, always record the value containing the highest value for that one task only.

For maintenance:

Enter the code found in column F4 of the RAS.

Block 15- Record for (T) greatest quantity of each AFSC required in columns 4, 5, 6, 7, or 8 for task completion.

Record for (F) a summary count of the greatest quantity of each AFSC required for the performance of any one task.

Block 16- For maintenance (T) record the accumulated time required for each AFSC type to perform the task, then add all times to provide a MAX task time.

For maintenance (F) record the MAX task time for the tasks within the function.

For operations (T) record as follows:

Time limitations - column 25 and 26
Start time - columns 27 and 28
Stop time - columns 29 and 30
Total clock time - columns 31 and 32
Each AFSC's time - total of columns 31 and 32 for each AFSC
Total man time - total as above for each AFSC times the number of AFSC's required

For operations (F) record the total clock time for the tasks within the function.

At this point complete Block 12 (See instructions for Block 12, page 157).

GUIDELINES FOR DATA EXTRACTION (SATURN)

General

The fundamental task to be performed is to extract the data from source materials and record them on the forms provided. The information should be recorded exactly as it appears in the source materials. Few judgments will be necessary on your part to complete the sixteen items on the forms.

Specific Instructions

Number forms sequentially beginning with 501. Place the number in the space labeled Index Number.

Block 1 - Will always be SV

Block 2 - Get date from bottom of each first analysis sheet of documents D5-16001-910 and D5-16001-523.

No revision letter for the -910 docume . Revision letters have been indluded in the -523 document as part of the P.E.N/OPS Activity No. e.g., 1523-12-C. "C" is the revision letter.

Block 3 - Will always be Unclassified

Block 4 - Will always be Boeing

Block 5 - Author for -901 will be found at bottom of first analysis sheet after "Engineer".

Author for -523 will be found at top of sheet in space "Prepared By".

Title will be as indicated

Block 6 - Will always be none when using -901 document.

When using -523 document references will be found at bottom of last "Equipment Maintenance" sheet.

Block 7 - Will always be Maintenance

Block 8 - If using -901 record (F) the name found in "Event Title" and "Event No.".

If using -523 record (T) then name in "Nomenclature" following "1" in column 4. "Indenture" on first sheet of Equipment Maintenance Sequence.

Block 9 - Will always be as follows:

Mission - Assembly Checkout, Launch Vehicle
Phase - Vehicle Systems Analysis, Pad, Fueled.
Segment - Maintenance Analysis.

Block 10- For (F) accumulate all special tools and equipment found in columns 1,2 and 3 of "Maintenance Requirements Analysis Form".

For (T) list sequentially all equipment found in Column 5 "Nomenclature" and Column 6 "Mfg. Model Part No." of "Equipment Maintenance Sequence" and also the equipment found in Column 3 of "Maintenance Requirements Analysis Form."

Block 11 - Will always be none
Block 12 - Although the section appears early in the form, it should be completed only after all other sections have been completed. Block contents will consist of:

Miscellaneous comments necessary to explain any of the other items

Record any "Cautions" or "notes"

Record any pre-function or pre-task conditions that must be accomplished before this event can be started.

Record any other information which you feel should be called to attention regarding the event.

Block 13 - If (F) copy sequence from "Sub Event" column in 907 document.

If (T) copy sequence of actions checked in columns I and II of first sheet of each "Equipment Maintenance Sequence".

Block 14 - Location will always be Kennedy Space Center, Launch Complex 39 Mobile Launcher, Launch Control Center.

Criticality will be the greatest criticality recorded for the event in "perf crit" column of the "Maintenance Analysis Requirements Analysis Form"

Criticality index is:

A - Little or no effect. Would not affect the mission success.
B - Could result in some degradation of equipment but would probably not affect mission success.
C - Mission success would be compromised to an unacceptable degree.

Block 15 - Record for (T), man type and greatest single quantity required for event completion. Record as found in Section D columns 2, 3, 4 of "Maintenance Requirements Analysis Form".

Record for (F) a composite summary of personnel required for each sub-event or task.

Block 16 - Record time in minutes but MAX Task Time is to be recorded in hours and minutes.

For (T), record time required to compile each required action. If more than one time is found for an action, record the largest as (MAX).

For (F) record MAX Task Time for each task.

At this point complete block 12.

APPENDIX VII

KEYPUNCHING GUIDELINES

KEYPUNCHING GUIDELINES

Every piece of input consists of a field number, one or more spaces, a value, and one or more spaces. The value is given to the element having that field number in the data base description.

1 (PREFLIGHT OPERATIONS) 2 TAXI

Values for string elements* are entered by repeating the element field number and a value.

9 THROTTLES 9 RUDDER 9 FLAPS

Values for elements in a string set are entered in the same way except that the order in which they are entered is important. The first value for an element in a string set is associated with the first value for every other element in that set, and so on. If a value for one element in a string set exists, an associated value for every other element in that set must also exist. Therefore, if no real values exist for certain elements in a string set, "dummy" values must be inserted. Values for a string set may be entered in either of the following ways:

6 10552 7 (TROOP CARRIER PILOT) 6 10452 7 (TRANSPORT PILOT)

or

6 10552 6 10452 7 (TROOP CARRIER PILOT) 7 (TRANSPORT PILOT)

One or more blanks may separate field numbers and values. If a value contains blanks or commas, it must be enclosed in parentheses. If a value contains embedded parentheses, left and right parentheses must match and the entire value must be enclosed in parentheses.

5 (INSPECT ANNUNCIATOR AND WARNING LIGHTS (USE TEST SWITCH))

A value may contain not more that 256 characters including blanks.

The end of all values for an entry is indicated by the entry terminator defined in the data base description. The end of all input is indicated by the word TERM.

Specified keypunching rules were also followed:

Columns 1 through 72 may contain data.

---

*Related string elements in an entry.

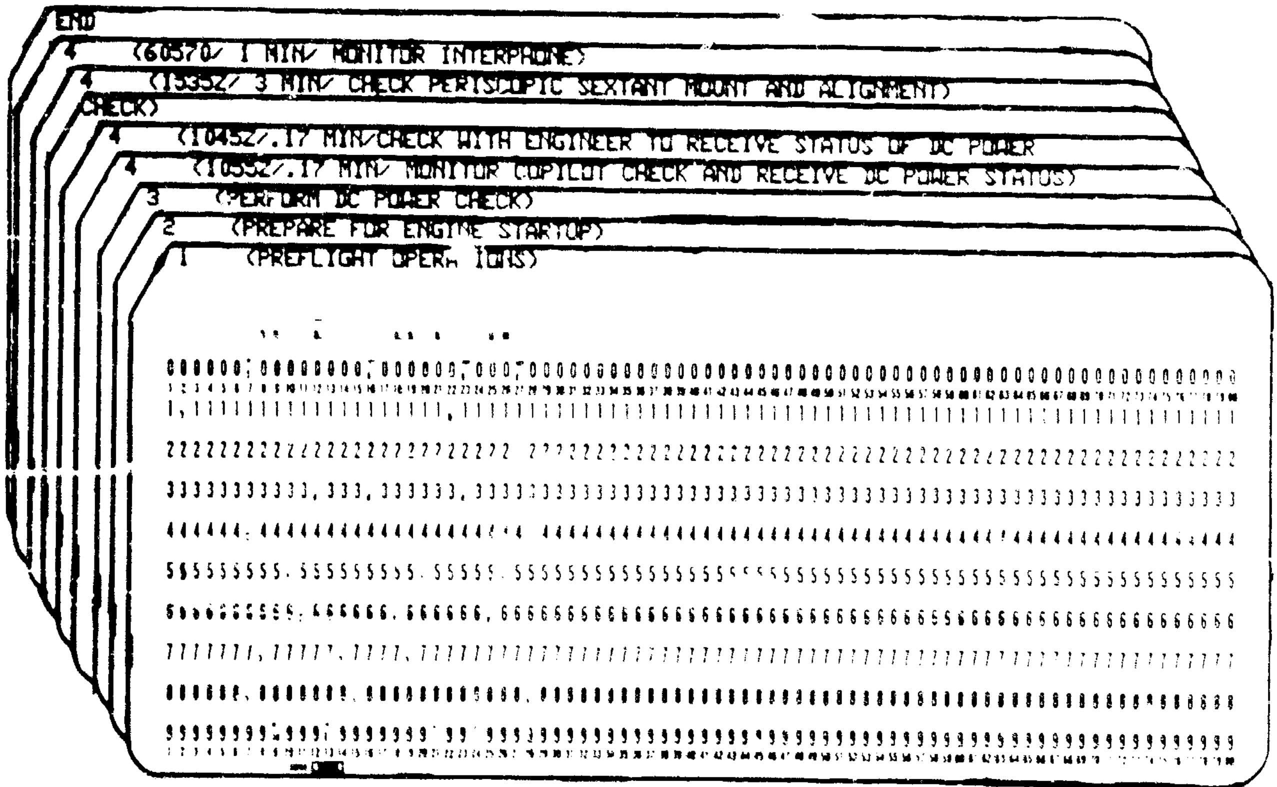
Column 1 of each card is treated as a continuation of the previous card, allowing a field number or value to extend between cards.

The entry terminator may not be split between cards.

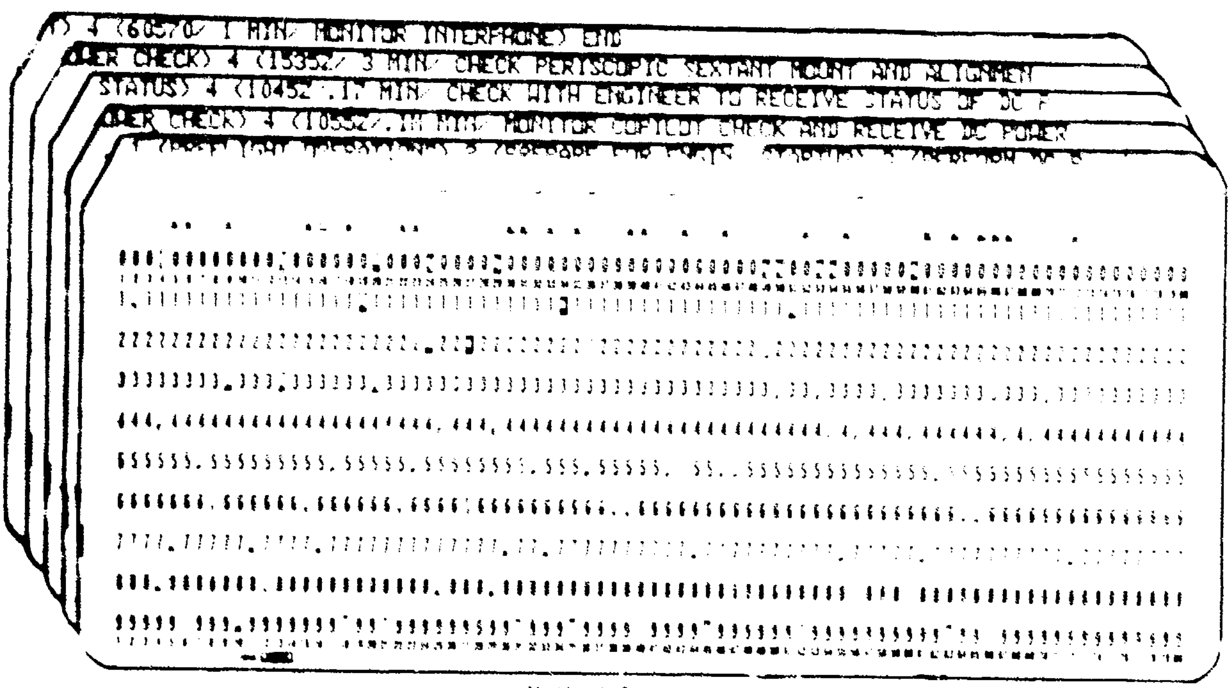
The input terminator, TERM, must exist on a card by itself.

Data values may be stored on cards in two ways. A field number and a value may exist on a card by themselves (figure 24) or a field number and a value may be immediately followed by another field number and value (figure 24). The first method provides much more ease in the desk editing of the data and correction of errors not discovered until the loading of the data base.

The second method provides for a savings of storage area and, in the event of large data bases, considerably reduces the time required to load the data base.



Method 1



Method 2

Figure 24 - Two Methods for Keypunching

APPENDIX VIII

C-5A DATA ELEMENTS

C-5A DATA ELEMENTS

The following is a list of elements in the C-5A data base as restructured for TTMS.

ENTRY NUMBER
ENTRY TYPE
MISSION PHASE
MISSION SEGMENT
TIME SEGMENT
TASK
    TASK VERB
    TASK STATEMENT
    TIME
    START TIME
    STOP TIME
    PERSONNEL
        AFSC OFFICER
        AFSC AIRMAN
        AIR FORCE SPECIALITY
        SHREDOUT
        POSITION TITLE
        PERSONNEL TIME
        PERSONNEL NUMBER
        DIFFICULTY
        CRITICALITY
        TRAINING REQUIREMENTS
        PERFORMANCE FREQUENCY
        EQUIPMENT VISISBILITY
        EQUIPMENT READABILITY
        EQUIPMENT REACHABILITY
        EQUIPMENT MANIPULABILITY
        SPECIAL SKILLS
    LOCATION
    EQUIPMENT
        EQUIPMENT ITEM
    SPECIAL TOOLS OR EQUIPMENT
        SPECIAL TOOLS OR EQUIPMENT ITEM
    TASK FREQUENCY
    HAZARDS
    SAFETY PRECAUTIONS
    [illegible]
        SOURCE IDENTIFICATION
    REVISION
    REVISION DATE
    REMARKS

APPENDIX IX

DEFINITION OF DATA ELEMENTS (TDMS)

DEFINITION OF DATA ELEMENTS (TDMS)

The following is an alphabetized list of all of the data elements contained in the TDMS (C-5A) data base. The list contains the definitions of each element.

AFSC AIRMAN - contains the Air Force Specialty Code of the airmen required to perform a task.

AFSC OFFICER - contains the Air Force Specialty Code of the officers required to perform a task.

AIR FORCE SPECIALTY - contains an alphanumeric designator of an ability or skill not restricted to a single utilization or career field for each individual involved in a task.

CRITICALITY - contains, for each individual, the degree of criticality associated with the performance of the task.

DIFFICULTY - contains, for each individual, the degree of difficulty associated with the performance of the task.

ENTRY DATE - contains the date the information was entered in the data base.

ENTRY NUMBER - contains a unique numerical identifier assigned to each entry as it is entered into the data base.

ENTRY TYPE - designates whether the data base entry describes a time segment as originally entered into the data base, or whether the entry has been subsequently updated. If update, the element contains a short description of the modification.

EQUIPMENT - contains no data values but is merely a heading for a repeating group of elements.

EQUIPMENT ITEM - contains the names or designators of the hardware associated with a specific task.

EQUIPMENT MANIPULABILITY - indicates how well an individual can manipulate the equipment utilized in performance of a task.

EQUIPMENT REACHABILITY - indicates how well an individual can reach the equipment utilized in performance of a task.

EQUIPMENT READABILITY - indicates how well an individual can read a display surface, gauge, etc,. utilized in performance of a task.

EQUIPMENT VISIBILITY - indicates how well an individual can see an item of hardware that is required for the performance of a task.

HAZARDS - contains information regarding the risk associated with performance of a given task.

LOCATION - describes the physical place associated with the performance of a task.

MISSION PHASE - contains the broadest level of mission profile information associated with the performance of task.

MISSION SEGMENT - contains a breakdown of the mission phase in which a task is performed.

PERFORMANCE FREQUENCY - indicates how often each individual involved in the task performs his assigned duties.

PERSONNEL - contains no data values but is merely a heading for a repeating group of data.

PERSONNEL NUMBER - contains a numeric value representing the number of each type of personnel required to perform a task.

PERSONNEL TIME - identifies the amount of time, in minutes, spent in the performance of a task by each of the personnel types involved in the task.

POSITION TITLE - contains the official title, e.g., pilot, radio repairman, of each type of personnel involved in the performance of a task.

REMARKS - contains any relevant miscellaneous comments associated with a task.

REVISION - contains the revision code associated with the last revision of the task.

REVISION DATE - contains the date of the latest revision.

SAFETY PRECAUTIONS - contains statements regarding precautions to be taken during the performance of a task.

SHREDOUT - contains an alphabetic suffix to the AFSC showing qualifications in specific equipment or functions.

SOURCE - contains no data values but is merely a heading for a repeating group of elements.

SOURCE IDENTIFICATION - contains the author, document refernces, originating organization, security classification and date associated with the analysis of a task.

SPECIAL SKILLS - contains statement identifying the visual, verbal, perceptual, motor, judgmental capabilities and the knowledge of theory required by individuals to properly perform a task.

SPECIAL TOOLS/EQUIPMENT - contains no data values but is merely a heading for a repeating group of elements.

SPECIAL TOOLS /EQUIPMENT ITEM - contains the items of special equipment required to perform a task.

START TIME - contains the time, in minutes, at which a task begins. Time is calculated chronologically from the start of the preflight phase, beginning at zero and continuing until the end of the post-flight phase.

STOP TIME - contains the stop time, in minutes, associated with the performance of a task.

TASK - contains no data values but is merely a heading for a repeating group of elements.

TASK FREQUENCY - describes how often a task is performed.

TASK STATEMENT - describes an action, performed by one or more individuals at specified times, directed at the accomplishment of a limited goal.

TASK VERB - contains the verb which describes the action or process of the task statement.

TIME - contains the total time, in minutes, required to perform a task.

TIME SEGMENT - identifies the segment of time during which a related group of tasks are performed.

TRAINING REQUIREMENTS - identifies those specific training requirements necessary personnel type involved in the performance of a task.

APPENDIX X

BUILD AND MATCH PROGRAM

BUILD AND MATCH PROGRAM

PROGRAM BUILD

```
START 72 BUILD
TABLE INPUT R 10 1 ;
  BEGIN
    ITEM IN H 8 0 0 N ;
    ITEM CH H 1 0 0 M ;
  END
TABLE OUTPUT R 512 1 ;
  BEGIN
    ITEM OUT H 8 0 0 N ;
  END
TABLE NAMES R 9 1 ;
  BEGIN
    ITEM NAME H 8 0 0 N ;
      BEGIN
        8H(NAME #1=)  8H(NAME #2=)  8H(NAME #3=)  8H(NAME #4=)  8H(NAME #5=)
        8H(NAME #6=)  8H(NAME #7=)  8H(NAME #8=)  8H(NAME #9=)
      END
  END
TABLE CODES R 9 1 ;
  BEGIN
    ITEM CODE H 8 0 0 N ;
      BEGIN
        8H(CODE #1=)  8H(CODE #2=)  8H(CODE #3=)  8H(CODE #4=)  8H(CODE #5=)
        8H(CODE #6=)  8H(CODE #7=)  8H(CODE #8=)  8H(CODE #9=)
      END
  END
ITEM T1 I 48 U ;
ITEM T2 I 48 U ;
ITEM PROFILE H 6 ;
ITEM END H 8 F 8H(END     ) ;
ITEM TELTYP H 6 F 6H(TELTYP) ;
ITEM YES H 1 F 1H(Y) ;
ITEM NO H 1 F 1H(N) ;
ITEM BLANK H 8 F 8H(        ) ;
```

```
PROC LDTTY ;
  BEGIN
    FOR A = 0,1,9 ;
    IN[A] = BLANK ;
    READ(TELTYP,INPUT,9) ;
  END
PROC XFER ;
ITEM AA I 48 U ;
  BEGIN
    FOR A = 0,1,9 ;
      BEGIN
        FOR B = 0,1,7 ;
          BEGIN
            IF BYTE(B,1,IN[A],8) EQ 20(?7) ;
            RETURN ;
            SBYT(B,1,OUT[AA+A],8,BYTE(B,1,IN[A],8)=OUT[AA+A]) ;
          END
      END
  END

A[illegible]. FOR A = [illegible] ;
OUT[A] = BLANK ;
FOR A = [illegible] ;
OUT[A+[illegible]] = [illegible] ;
OUT[[illegible]] = [illegible] ;
PRINT [illegible] PROFILE NAME[illegible] ;
A[illegible]. [illegible]TTY ;
[illegible] ;
[illegible] = BYTE [illegible] ;
FOR A = [illegible] ;
OUT[A] = BLANK ;
[illegible] BLANK[illegible] ;
[illegible] ;
A[illegible]. PRINT [illegible] ;
[illegible]TTY ;
IF [illegible] EQ N ;
[illegible] A[illegible] ;
```

```
IF CH NQ YES ;
GOTO A30 ;
PRINT 12H(ENTER SYSTEM) ;
RDTTY ;
XFER(0) ;
A40.  PRINT 14H(LIMIT MISSION?) ;
RDTTY ;
IF CH EQ NO ;
GOTO A50 ;
IF CH NQ YES ;
GOTO A40 ;
PRINT 11H(ENTER PHASE ;
RDTTY ;
XFER(10) ;
PRINT 13H(ENTER SEGMENT) ;
RDTTY ;
XFER(20) ;
IF OUT[20] EQ 8H(NONE    ) ;
OUT[20] EQ BLANK ;
A50.  PRINT 15H(LIMIT FUNCTION?) ;
RDTTY ;
IF CH EQ NO ;
GOTO A60 ;
IF CH NQ YES ;
GOTO A50 ;
PRINT 14H(ENTER FUNCTION) ;
RDTTY ;
XFER(30) ;
A60.  PRINT 15H(LIMIT HARDWARE?) ;
RDTTY ;
IF CH EQ NO ;
GOTO A70 ;
IF CH NQ YES ;
GOTO A60 ;
FOR A = 0,1,8 ;
  BEGIN
```

```
      RITE(TELTYP,NAMES+A,1) ;
      RDTTY ;
      XFER(40+10*A) ;
      IF OUT[40+10*A] EQ ND ;
      GOTO A70 ;
    END
  OUT[130] = ND ;
  A70.  PRINT 16H(LIMIT PERSONNEL?) ;
  IF CH EQ NO ;
  GOTO A80 ;
  IF CH NQ YES ;
  GOTO A70 ;
  FOR A = 0,1,8 ;
    BEGIN
      RITE(TELTYP,CODES+A,1) ;
      RDTTY ;
      XFER(140+10*A) ;
      IF OUT[140+10*A] EQ ND ;
      GOTO A80 ;
    END
  OUT[230] = ND ;
  A80.  [illegible](PROFILE,0,OUTPUT,[illegible]) ;
  A[illegible].  PRINT [illegible](PROFILE COMPLETED, ANOTHER [illegible]?) ;
  RDTTY ;
  IF CH EQ YES ;
  [illegible] A[illegible] ;
  IF CH NQ NO ;
  [illegible] A[illegible] ;
  [illegible] ;
  TERM A[illegible] ;
```

PROGRAM MATCH

```
START 72 MATCH
  TABLE DATA R 512 1 ;
    BEGIN
      ITEM D1 H 8 0 0 N ;
    END
  TABLE PROFL R 500 1 ;
    BEGIN
      ITEM P1 H 8 0 0 N ;
    END
  TABLE INPUT R 1 1 ;
    BEGIN
      ITEM IN H 6 0 0 M ;
    END
  TABLE OUTPUT R 18 1 ;
    BEGIN
      ITEM OUT H 8 0 0 N ;
        BEGIN
          8H(SYSTEM -) 8H(        ) 8H( TASK - ) 8H(        )
          8H(        ) 8H(        ) 8H(        ) 8H(        )
          8H(        ) 8H(ENTRY # ) 8H(        ) 8H( TYPE - )
          8H(        ) 8H(        ) 8H(        ) 8H(        )
          8H(        ) 8H(        )
        END
    END
  TABLE NXTFLD R 400 1 ;
    BEGIN
      ITEM FLD H 8 0 0 N ;
    END
  ITEM MTCH H 1 ;
  ITEM T1 I 48 U ;
  ITEM SYSTEM H 6 ;
  ITEM DCOL I 48 U ;
  ITEM DROW I 48 U ;
```

```
ITEM CONWRD I 48 U ;
ITEM PROW I 48 U ;
ITEM NUENT H 1 ;
ITEM NOENT H 1 ;
ITEM SCTRNO I 48 U ;
ITEM CHAR I 48 U ;
ITEM FRSTM I 48 U ;
ITEM FLAG H 1 ;
ITEM YES H 1 P 1H(Y) ;
ITEM NO H 1 P 1H(N) ;
ITEM WRDS1 I 48 U ;
ITEM WRDS2 I 48 U ;
ITEM NUM H 2 ;
ITEM BLANK H 8 P 8H(        ) ;
PROC CHKIT ;
  BEGIN
    IF BYTE(7,1,D1,[DROW],8) EQ 20(76) ;
      BEGIN
        REED.  RDX1(SYSTM,SCTRNO,DATA,512=T1) ;
        SCTRNO = SCTRNO + 1 ;
        DROW = 0 ;
        DCOL = 0 ;
      END
    IF BYTE(7,1,D1[DROW],8) EQ 20(75) ;
    GOTO REED ;
    IF BYTE(7,1,D1[DROW],8) EQ 20(77) ;
      BEGIN
        PRINT 1H( ) ;
        PRINT 13H(ERROR IN DATA) ;
        STOP ;
      END
  END
PROC MOVIT ;
ITEM PAREN I 48 U ;
  BEGIN
```

```
FOR A = 0,1,8 ;
  BEGIN
    FLD[A] = BLANK ;
  END
CHAR = 0 ;
FOR A = 0,1,36 ;
  BEGIN
    FOR B = 0,1,7 ;
      BEGIN
        TST. IF BYTE(DCOL,1,D1[DROW],8) EQ 1H( ) ;
          BEGIN
            IF CHAR EQ 0 ;
              BEGIN
                HIT ;
                GOTO TST ;
              END
            IF PAREN EQ 0 ;
            RETURN ;
            GOTO MOVE ;
          END
        IF BYTE(DCOL,1,D1[DROW],8) EQ 1H(() ;
          BEGIN
            IF PAREN EQ 0 ;
              BEGIN
                PAREN = 1 ;
                HIT ;
                GOTO TST ;
              END
            PAREN = PAREN + 1 ;
            GOTO MOVE ;
          END
        IF BYTE(DCOL,1,[DROW],8) EQ 1H());
          BEGIN
            IF PAREN EQ 1 ;
              BEGIN
```

```
                    PAREN = 0 ;
                    HIT ;
                    RETURN ;
                  END
                PAREN = PAREN - 1 ;
                GOTO MOVE ;
              END
            MOVE.  SBYT(B,1,FLD[A],8,BYTE(DCOL,1,D1,[DROW],8)=FLD[A]) ;
            CHAR = CHAR + 1 ;
            HIT ;
          END
        END
      END
    PROC HIT ;
      BEGIN
        DCOL = DCOL + 1 ;
        IF DCOL EQ 8 ;
          BEGIN
            DCOL = 0;
            DROW = DROW + 1 ;
            CONWRD = CONWRD + 1 ;
            IF CONWRD EQ 10 ;
              BEGIN
                IF BYTE(7,1,D1[DROW],8) EQ 20(32);
                  BEGIN
                    DROW = DROW + 1 ;
                    RETURN ;
                  END
                CHKIT;
              END
          END
      END
  PROC MTCHIT ;
    BEGIN
      YY.  FOR A = 0,1,8 ;
        BEGIN
```

```
        IF P1[PROW+A] NQ FLD[A] ;
          BEGIN
            ZZ.  MTCH = NO ;
            RETURN ;
          END
        MTCH = YES ;
      END
    END
  PROC NOWRDS ;
    BEGIN
      FOR A = 0,1,8 ;
        BEGIN
          IF OUT[A] EQ BLANK ;
            BEGIN
              OUT[A] = 160(3277606060606060) ;
              WRDS1 = A + 1 ;
              GOTO QQ ;
            END
        END
      SBYT(7,1,OUT[8],8,20(32)=OUT[8]) ;
      QQ.  FOR B = 9,1,17 ;
        BEGIN
          IF OUT[B] EQ BLANK ;
            BEGIN
              OUT[B] = 160(3277606060606060) ;
              WRDS2 = B - 8 ;
              RETURN ;
            END
        END
      SBYT(7,1,OUT[17],8,20(32)=OUT[[illegible]]) ;
      WRDS2 = 9 ;
    END
  PROC FLDNUM ;
    BEGIN
      NUENT = 1H( ) ;
      NOENT = 1H( ) ;
```

```
FIND.  IF BYTE(DCOL,1,D1,[DROW],8) EQ 1H( );
  BEGIN
    HIT ;
    GOTO FIND ;
  END
IF BYTE(DCOL,3,D1[DROW],8) EQ 3H(END) ;
  BEGIN
    NUENT = YES ;
    HIT ;
    HIT ;
    HIT ;
    GOTO FIND
  END
IF BYTE(DCOL,4,D1[DROW],8) EQ 4H(TERM) ;
  BEGIN
    NOENT = YES ;
    RETURN ;
  END
NUM = BYTE(DCOL,2,D1[DROW],8) ;
HIT ;
HIT ;
MOVIT ;
IF NUM EQ 2H(1 ) ;
  BEGIN
    FOR W = 0,1,8 ;
      BEGIN
        IF BYTE(W,1,FLD[0],8) EQ 1H( ) ;
          BEGIN
            SBYT(W,1,FLD[0],8,1H(;)=FLD[0]);
            GOTO WW ;
          END
      END
    WW.  SBYT(0,4,OUT[10],8,BYTE(0,4,FLD[0],8)=OUT[10]) ;
  END
IF NUM EQ 2H(2 ) ;
  BEGIN
```

```
          FOR A = 0,1,5 ;
          OUT[12+A] = FLD[A] ;
        END
      IF NUM EQ 2h(11) ;
        BEGIN
          FOR A = 0,1,5 ;
          OUT[3+A] = FLD[A] ;
        END
      IF NUM EQ 2H(1 ) OR NUM EQ 2H(8 ) OR NUM EQ 2H(9 ) OR NUM EQ 2H(10) OR
      NUM EQ 2H(14) OR NUM EQ 2H(21) ;
      RETURN ;
      GOTO FIND ;
    END

  AA.  FOR A = 0,1,512 ;
  D1[A] = BLANK ;
  FOR B = 0,1,500 ;
  P1[B] = BLANK ;
  CONWRD = 1 ;
  FRSTM = 1 ;
  FLAG = 1H( ) ;
  PRINT 1H( ) ;
  PRINT 18H(ENTER PROFILE NAME) ;
  READ(6H(TELTYP),INPUT,1) ;
  FOR B = 0,1,7 ;
    BEGIN
      IF BYTE(B,1,IN,8) eq 20(32) ;
      SBYT(B,1,IN,8,1H( )=IN) ;
    END
  IF BYTE(0,4,IN,8) EQ 4H(NONE) ;
    BEGIN
      PRINT 1H( ) ;
      PRINT 15H(MATCH CONCLUDED) ;
      STOP ;
    END
```

```
PRINT 1H( ) ;
PRINT 7H(STANDBY) ;
BB.  FIL3(IN,11,1H(C),0,IN,0,0,500=T1,T1,T1) ;
RDX1(IN,0,PROFL,500=T1) ;
IF P1 EQ BLANK ;
SYSTM = 6H(SYMALC) ;
IF BYTE(0,4,P1,8) EQ 4H(ALCC) ;
  BEGIN
    SYSTM = 6H(SYMALC) ;
    OUT[1] = 8H( ALCC;   ) ;
  END
IF BYTE(0,4,P1,8) EQ 4H(C-5A) ;
  BEGIN
    SYSTM = 6H(SYMC5A) ;
    OUT[1] = 8H( C-5A;   ) ;
  END
IF BYTE(0,6,P1,8) EQ 6H(SATURN) ;
  BEGIN
    SYSTM = 6H(SYMSAT) ;
    OUT[1] = 8H( SATURN;) ;
  END
BB1.  FIL3(SYSTM,11,1H(C),0,SYSTM,0,0,10000=T1,T1,T1) ;
RDX1(SYSTM,0,DATA,512=T1) ;
SCTRNO = 1 ;
DCOL = 0 ;
DROW = 0 ;
BB2.  FLDNUM ;
BB3.  PROW = 10 ;
MTCH = YES ;
IF NOENT EQ YES ;
GOTO ENDIT ;
CC.  IF P1[10] EQ BLANK ;
GOTO EE ;
DD.  IF NUM NQ 2H(3 ) ;
  BEGIN
```

```
    FLDNUM ;
    IF NUENT EQ YES ;
    GOTO BB3 ;
    GOTO DD ;
  END
MTCHIT ;
IF MTCH EQ NO ;
GOTO XX ;
FLDNUM ;
IF NUENT EQ YES ;
GOTO BB3 ;
EE.  PROW = 20 ;
IF P1[20] EQ BLANK ;
GOTO GG ;
FF.  IF NUM NQ 2H(9 ) ;
  BEGIN
    FLDNUM ;
    IF NUENT EQ YES ;
    GOTO BB3 ;
    GOTO FF ;
  END
MTCHIT ;
IF MTCH EQ NO ;
GOTO XX ;
FLDNUM ;
IF NUENT EQ YES ;
GOTO BB3 ;
GG.  PROW = 30 ;
IF P1[30] = BLANK ;
GOTO II ;
HH.  IF NUM NQ 2H(10) ;
  BEGIN
    FLDNUM ;
    IF NUENT EQ YES ;
    GOTO BB3 ;
    GOTO HH ;
```

```
  END
MTCHIT ;
IF MTCH EQ NO ;
GOTO XX ;
FLDNUM ;
IF NUENT EQ YES ;
GOTO BB3 ;
II.  IF P1[40] EQ BLANK ;
GOTO LL ;
JJ.  IF NUM NQ 2H(14) ;
  BEGIN
    FLDNUM ;
    IF NUENT EQ YES ;
    GOTO BB3 ;
    GOTO KK ;
  END
KK.  FOR H = 40,10,130 ;
  BEGIN
    IF P1[H] EQ 8H(END     ) ;
      BEGIN
        FLDNUM ;
        IF NUENT EQ YES ;
        GOTO BB3 ;
        IF NUM NQ 2H(14) ;
        GOTO XX ;
        GOTO KK ;
      END
    PROW = H ;
    MTCHIT ;
    IF MTCH EQ YES ;
    GOTO LL ;
  END
LL.  IF P1[140] EQ BLANK ;
GOTO XX ;
MM.  IF NUM NQ 2H(21) ;
```

```
  BEGIN
    FLDNUM ;
    IF NUENT EQ YES ;
    GOTO BB3 ;
    GOTO MM ;
  END
NN.  FOR P = 140,10,230 ;
  BEGIN
    IF P1[P] EQ 6H(END      ) ;
      BEGIN
        FLDNUM ;
        IF NUENT EQ YES ;
        GOTO BB3 ;
        IF NUM NQ 2H(21) ,
        GOTO XX ;
        GOTO NN ;
      END
    PROW = P ;
    MTCHIT ;
    IF MTCH EQ YES ;
    GOTO XX ;
  END
XX.  IF NUENT EQ YES ;
  BEGIN
    FLDNUM ;
    GOTO XA ;
  END
IF MTCH EQ YES ;
  BEGIN
    NOWRDS ;
    PRINT 1H( ) ;
    RITE(6H(TELTYP),OUTPUT,WRDS1) ;
    RITE(6H(TELTYP),OUTPUT+9,WRDS2) ;
    FLAG = YES ;
  END
```

```
GOTO BB3 ;
ENDIT.  IF P1 EQ BLANK ;
  BEGIN
    IF FRSTM EQ 1 ;
      BEGIN
        SYSTM = 6H(SYMC5A) ;
        OUT[1] = 8H( C-5A ; ) ;
        FRSTM = FRSTM + 1 ;
        GOTO BB1 ;
      END
    IF FRSTM EQ 2 ;
      BEGIN
        SYSTM = 6H(SYMSAT) ,
        OUT[ ] = 8H( SATURN;) ;
        FRSTM = FRSTM + 1 ;
        GOTO BB1 ;
      END
  END
IF FLAG EQ YES ;
  BEGIN
    PRINT 1H( ) ;
    PRINT 15H(MATCH CONCLUDED) ;
    GOTO AA ,
  END
PRINT 1H( ) ;
PRINT 8H(NO MATCH) ;
GOTO AA ,
TERM AA ;
```

APPENDIX XI

FACETED CLASSIFICATION ELEMENT NAMES AND DEFINITIONS

FACETED CLASSIFICATION ELEMENT NAMES AND DEFINITIONS

The primary sources for the definition of these terms were: the Handbook of Instructions for Aerospace Personnel Subsystem Design AFSCM 80-3; Policies, Procedures and Criteria, AFM 26-1; Military Personnel Classification Policy Manual, AFM 35-1; Officer Classification Manual 36-1; Airman Classification Manual, AFM 39-1, and an examination of time-lines of aerospace systems. The terms in the list are ordered to adhere to the classification structure since this is more meaningful than an alphabetical arrangement.

1. SYSTEM - A composite of equipment, skills, and techniques capable of performing and/or supporting an operational (or nonoperational) role. An operational role refers to a system program wherein the system is intended for use by an operational command. A nonoperational role refers to a system program wherein the system/equipment is intended for use for other than operational employment by using commands. Extended test support equipment are often nonoperational in this sense. A complete system includes related facilities, equipment, material services and personnel required for its operation to the degree that it can be considered a self-sufficient unit in its intended operational (or nonoperational) and/or support environment.

2. PHASE - A major division of the operational or support role of a system. For example, in an aerospace system, ground maintenance and flight operations constitute phases.

3. SEGMENT - A major division of phase. For example in an aerospace system, flight line maintenance and bench maintenance would constitute subdivisions of ground maintenance; cruise, and approach and landing are subdivisions of flight operations.

4. TASK - A related group of subtasks, performed by one or more individuals at specified or unspecified times during the operation and maintenance of a system, that are directed to the accomplishment of limited goals. Tasks are most often performed at specified times, although they may be performed continuously or on an as-required basis, throughout the system's cycle. A task may consist of a single operation when there are no subtasks that must

be performed before the task can be completed. For example, tuning a radio transmitter to a desired frequency is a task consisting of a related group of subtasks. Rotating a switch on a radio transmitter to change from one transmission frequency to another qualifies as a task since the single operation completes the limited goal. An operation of the latter type would be a subtask if it were in a related series of actions required to tune the transmitter.

5. TASK TYPE - An independent subtask (a task that involves a single individual) and coordinated task (a task that involves more than one individual in its performance)

6. TASK SEQUENTIAL ORDER - The order of task start time calculated from the beginning of a segment. The sequential order is designated by a number. For example, 7 would indicate that this task was the seventh task to start at a different sequentially ordered time since the beginning of the segment. If more than one task starts at the same time, a decimal point is placed after the sequential order number. For example, 7.1 and 7.2 indicate that two tasks start at sequential order 7.

7. TASK SEQUENTIAL DEPENDENCIES - Tasks that are sequentially related to each other. This type of relationship stipulates that the performance of each subsequent task in the sequence after the first task, is dependent upon the accomplishment of the previous task. Within a dependent sequence of tasks, there may be secondary dependent sequences, but these remain as parts of the overall dependent sequence. For example, if two specialists are to complete separate tasks in a dependent sequence it would be possible for one specialist to complete his task without the other doing likewise. But the failure to complete both of the tasks would, of course, result in a failure to complete the task sequence and to satisfactorily accomplish its objective.

8. TASK TIME - Task time is classified as Specific if the task both occurs at a fixed point in the system's cycle and has a known time duration. Specific time can be expressed by numerical values that indicate its time interval or duration length. If a task is only performed when a special need arises, it is expressed by the term As Required. For example,

emergency procedures are performed on an as-required basis. If a task is performed continually or periodically throughout a segment, then task time is expressed by the term Continuous. A continuous task is often performed while a series of tasks with specific times is also performed. Generally, the continuous tasks are performed without interfering with the performance of specific tasks. Examples of continuous tasks are: monitor intercom; maintain directional control of the aircraft.

9. TOTAL TASK TIME - A numerical value that expresses the amount of time required to perform a task. Total task time is expressed by minutes and hundredths of minutes.

10. TASK INTERVAL TIME - Two numerical values that express the interval in which the task is to be performed. The two numerical values represent the start and stop times associated with the task. Task interval time is expressed in terms of minutes and hundredths of minutes.

11. SUBTASK (repeating group) - One of a series of related actions, performed by one or more individuals, required to accomplish the limited goal of a task. For example, the individual steps required to tune a transmitter are the subtasks. If a task goal requires a single action, the task and subtask are regarded as one and the same (see item 4).

12. SUBTASK TYPE - An independent subtask (a subtask that involves a single individual) or a coordinated subtask (a subtask that involves more than one individual in its performance)

13. ACTION VERB - An expression of the act or process of producing an effect or performing a function. The action verbs must always be in the present tense and in the indicative mood.

14. ACTION DESCRIPTION - A short descriptive statement, beginning with the action verb, that describes the action that is taking place in the subtask. For example, adjust (action verb) trim or aircraft for level flight.

15. SUBTASK SEQUENTIAL ORDER - The order of subtask start time calculated from the initiation of a task. The sequential order is designated by a number. For example, 5 would indicate that a subtask was the fifth subtask in sequential order to start at a different time since the start of the task. If more than one subtask starts at the same time, a decimal point is placed after the sequential order number. For example, 5.1 and 5.2 indicate two subtasks starting at sequential order 5.

16. SUBTASK SEQUENTIAL DEPENDENCIES - Subtasks that are sequentially related to each other. This type of relationship stipulates that the performance of each subsequent subtask in the sequence after the first subtask is dependent upon the accomplishment of the previous task. Within a dependent sequence of subtasks, there may be secondary dependent sequences, but these remain as parts of the overall dependent sequence. For example, if two specialists are to complete separate subtasks in the same task, it is possible for one specialist to complete his assignment without the others doing so. The failure to complete all of the subtasks would, of course, result in a failure to complete the task and to satisfactorily accomplish its objective.

17. TOTAL SUBTASK TIME - A numerical value that expresses the amount of time required to perform a subtask. Total subtask time is expressed by minutes and hundredths of minutes.

18. SUBTASK INTERVAL TIME - Two numerical values that express the interval in which the subtask is to be performed. The two numerical values represent the start and stop times associated with the subtask. Subtask interval time is expressed by minutes and hundredths of minutes.

19. AIR FORCE SPECIALITY CODE (AFSC) - A code consisting of a combination of digits, or digits and letters, used to identify a given Air Force specialty. For example, 1538 signifies Navigator, an officer AFSC, and 60570 signifies Transportation Supervisor, an airman AFSC. A letter prefix and suffix may be assigned to both officer and airman AFSC's.

20. UTILIZATION FIELD - The first two digits of the officer AFSC. It signifies a grouping of Air Force officer specialties closely related on the basis of required skills and knowledge. For example, the Pilot Utilization Field

(10 through 14) encompasses the function of program formulation, policy planning, inspection, training and direction and performance of combat and operations activities as they relate to aircraft. In certain cases, the skills and knowledge required for a given utilization field are of such a specialized nature that they are not directly related to those required by another. When this condition occurs, the specialty and utilization field are the same.

21. UTILIZATION FIELD DESCRIPTION - A statement of what the utilization field number refers to. For example, 10 through 14 identifies the pilot utilization field.

22. CAREER AREA - The third digit of the officer AFSC, in combination with the first two digits. It signifies a grouping of officer utilization fields that are broadly related on the basis of required skills and knowledge. For example, 143 the Air Operations Career Area, encompasses those utilization fields directly required to employ weapon and supporting systems to accomplish the primary operational mission of the Air Force. Included in the area are the Pilot, Navigator-Observer, Aircraft Control, Weapons Director, Missile Operations, and Safety Utilization Fields.

23. CAREER AREA DESCRIPTION- A statement of what the Career Area number refers to. For example, 143 identifies Air Operations Career Area.

24. LEVEL OF QUALIFICATION - The fourth digit of the officer AFSC. It indicates the level of qualification within a career area. The level signifies potential, partial or full qualification.

25. LEVEL OF QUALIFICATION DESCRIPTION - A statement of what the Level of Qualification number refers to. For example, 1435 identifies fully qualified.

26. CAREER FIELD - The first two digits of the airman AFSC. It signifies a grouping of related Air Force specialties involving basically similar knowledge and skill. For example, the airman Transportation Career

Field, 60, encompasses the functions involved in the movement of personnel and materials by military and commercial transporation facilities.

27. CAREER FIELD DESCRIPTION - A statement of what the career field number refers to. For example, 60 identifies the Transportation Career Field.

28. CAREER FIELD SUBDIVISION - The third digit in combination with the first two digits of the airman AFSC. It signifies a division of a career field into which closely related Air Force specialties are arranged in one or more ladders to indicate lateral functional relationships. There are seven career field subdivisions under Transportation Career Field. For example, 605.

29. CAREER FIELD SUBDIVISION DESCRIPTION - A statement of what the career field subdivision number refers to. For example, 605 indicates Air Transportation Career Field.

30. CAREER FIELD LADDER - The fourth digit of an airman AFSC. It signifies a vertical arrangement of Air Force specialties within a career field subdivision to indicate skill distinction and progression. For example, 6057.

31. CAREER FIELD LADDER DESCRIPTION - A statement of what the career field ladder number refers to. For example, 6057 the level of technician or supervisor (advanced).

32. AIR FORCE SPECIALTY - The fifth digit of an airman AFSC in combination with the first four digits. It signifies a functional grouping of positions related in terms of education, training, experience, and ability qualifications. For example, 60570.

33. AIR FORCE SPECIALTY DESCRIPTION - A statement of what the Air Force specialty number refers to. For example, 60570 indicates Air Transportation Supervisor.

34. AIR FORCE SPECIALTY SHREDOUT - An alphabetical suffix on an officer or airman AFSC. It signifies qualification with specific equipment or functions encompassed by that Air Force specialty. For example, Z.

35. AIR FORCE SPECIALTY SHREDOUT DESCRIPTION- A statement of what the alphabetical suffix refers to. For example, 60570Z indicates the C-5A aircraft.

36. AIR FORCE SPECIALTY PREFIX - An alphabetical prefix on an officer or airman AFSC. It signifies an ability or skill not restricted to a single utilization field or career field. For example, L.

37. AIR FORCE SPECIALTY PREFIX DESCRIPTION- A statement of what the alphabetical prefix refers to. For example, L indicates Latin America Area Specialist.

38. EQUIPMENT TYPE - A fundamental grouping of hardware. The criterion for determining whether or not a unit of equipment should be classified as a type will depend upon whether it is a part of a larger assembly or is independent. For example, aircraft is a type of equipment because it is functionally complete item in itself and not a part of a larger equipment grouping.

39. PROPULSION UNIT - The type of power source used to propel the vehicle. For example, jet, reciprocating engine or rocket engine.

40. FUNCTION - The major purpose for which a type of equipment will be used. For example, equipment type is aircraft, the function is bomber. Function does not specify what kind of bomber it is.

41. SUBTYPE - A modifier of function that makes its meaning more precise. For example, function is bomber, subtype is heavy bomber.

42. MODEL - An alphanumeric designator which specifies a particular distinctive grouping of an equipment subtype. For example, subtype is heavy bomber, model is B-52.

43. MODIFICATION - A sequentially arranged series of alphabetic designators starting with A which indicates physical alterations to an equipment model to change its capabilities or characteristics. For example, model B-52, modification H.

44. SERIAL NUMBER - An alphanumeric designator which uniquely identifies an individual unit of equipment. It is not meant to designate identical units of equipment. A serial number will, for example, identify one particular B-52H from all others.

45. MAJOR COMPONENT MEMBER (repeating group in Subtask) - A basic indispensable segment of a unit of equipment. For example, the major components of an aircraft, include the fuselage, empennage, wings, landing gear (minus tires) and engines. Major components do not include accessories or other parts that may be replaced from time to time.

46. MAJOR COMPONENT - A particular major component of a unit of equipment under consideration. For example, engine.

47. COMPONENT MEMBER (repeating group in major component) - A self-contained unit which performs a function necessary to the proper operation of a module, subsystem, or system of which it is a part. For example, a generator and a gyroscope are components of an aircraft. A component may or may not be a member of a major component.

48. COMPONENT - Designates a particular component of a unit of equipment under consideration. For example, gyroscope.

49. ASSEMBLY MEMBER (repeating group in component) - A number of parts or sub-assemblies or any combination thereof that may be joined together to perform a specific purpose within a component.

50. ASSEMBLY - Designates a particular assembly of a component of equipment under consideration. For example, a radio receiver tuner.

51. SUBASSEMBLY MEMBER (repeating group in Assembly - Two or more parts which

form a portion of an assembly or component, replaceable as a whole, and having a part or parts which are individually replaceable.

52. SUBASSEMBLY - Designates a particular subassembly of an equipment assembly under consideration. For example, a radio receiver tuner bandspread.

53. PART MEMBER (repeating group in subassembly) - An individual piece or member of an equipment subassembly.

54. PART - Designates a particular individual piece or member of an equipment subassembly. For example, variable tuning capacitor.

APPENDIX XII

TIME-LINE PRINTOUTS

TIME-LINE PRINTOUT

A capability exists to output a crude time-line using TDMS, COMPOSE and the data in the experimental data pool. Time-line outputs are limited to the teletypewriter console characteristics which allow a single line output length of 70 characters or spaces. Therefore, by using the column or angle commands of query and specifying the maximum number of characters and spaces outputs similar to Figures 25, 26, and 27 are possible.

MISSION TIME (MINUTES)	OPERATOR SUB TASK 10552	OPERATOR SUB TASK 1045	OPERATOR SUB TASK 1585	OPERATOR SUB TASK 1535
372.00	28-1	28-1	28-2	27-4
372.25	28-1	28-4	28-2	27-4
372.50	28-1	28-4	28-2	
372.75	28-1	28-4	28-2	
373.00	28-1	28-4	28-3	28-6
373.25	28-1	28-4	28-3	28-6
373.50	28-1		28-3	28-6
373.75	28-1		28-3	28-6
374.00	28-5		28-3	28-6

Figure 25. Te ime-Line / Mission Time

Figure 25 presents a simulation processing output that permits the comparison between various crew members performing tasks by task computer element (28) and sub-task computer element (28-1) number as a function of elapsed time within a mission time. Blanks signify that an operator does not have an assigned task during this time segment. Since most of the task numbers are within computer element (28), it must be assumed that the task number (27-4) being performed by an operator (AFSC 1535) is a carry-over from the previous time segment. A further generalization may also be made; operators (AFSC 10552 and AFSC 1585) are active 100% of the time during this time segment, and operators (AFSC 1045 and 1535) have 0.75 and 0.50 minutes of uncommitted time during this time segment.

OPERATOR	QTY	START TIME	STOP TIME	TASK NO	SEGMENT	LOCATION	HELPER	CRIT	DIFF
10552	1	272.58	272.61	28-1	TAXI	WA#1PILOT	10570	NA	NA
10570	1	272.58	272.61	28-2	TAXI	WA#5CARGO		NA	NA
10550	1	272.58	272.61	28-5	TAXI	WA#5CARGO		NA	NA
1585	1	272.58	272.61	27-6 CONT	TAXI	WA#1FTENG		MOD	LOW
1535	1	272.58	272.61	28-4	TAXI	WA#1NAV		VRY	VRY
1585	1	272.58	272.61	28-3	TAXI	WA#1FTENG		LOW	LOW

Figure 26 Mission Segment Task Time-Line

Figure 26 presents a simulation output that permits a slightly different configuration of operator task assignments during a specified mission segment. This arrangement of the data is by operator and task start/stop time values. The output also contains some additional information (Mission Segment, Location, Helper, Task Criticality, and Task Performance Difficulty). Thus, the time-line may be individually structured by the system user to contain and order only those data elements or data element values selected from the data pool.

TIME SEG	OPERATOR	QTY	TASK TIME	TASK NO	LOCATION	EQUIPMENT
425	43270	01	435	176-1	WA#38FLTLN	ALIGNMENT FIXTURE A00108A BEAM TYPE SLING MR0228A
	43250	02				ENGINE MAINT STAND NOSE
	43230	01				COWL ENGINE INSTALLATION PIN KIT
426	43250	02	49.8	176-2	WA#40SHOP	AS ABOVE FOR TASK 176-1 PLUS TRANSPORTER TRUCK
427	43270	01	528.5	176.3	WA#46DFCTY	AS FOR 176-2 LESS TRUCK PLUS RAIL-TYPE TRANSPORTATION TRAILER MR0248A COMMON HAND TOOLS

Figure 27 Maintenance Task Time-Line

Figure 27 provides a third look at an initial time-line based upon maintenance data from the experimental data pool. In this example the display ordering is based on an artificially imposed element--Time Segment--because unscheduled maintenance must include some type of a hierarchical indexing scheme to assist in implementing retrieval. Therefore, this maintenance time-line is ordered by time segment and operator. Further, this output contains user specified qualifiers: quantity of operators, task identifying number, task location, and equipment required.

APPENDIX XIII

SIMULATION OUTPUT TECHNIQUE

SIMULATION OUTPUT

D. A. Wilson (1967), of the U. S. Naval Personnel Research Activity, San Diego, California developed a scheme for automating Operational Sequence Diagrams (OSD). The OSD is a specialized form of task analysis output developed for the U. S. Navy. It does not replace the requirements for a complete task analysis. This methodology, with some minor modifications, can be programmed as the fixed format output, for PSES, of a time-line or simulation run. This appendix provides an example of the simulation output available using the OSD techniques. The behavior codes used are as shown below:

FIRST LETTER HUMAN OR MACHINE	H(HUMAN) M(MACHINE)
SECOND LETTER BEHAVIOR	A(ACT) D(DECADE) T(TRANSMIT) R(RECEIVE) S(STORE) P(USE PREVIOUSLY STORED INFORMATION)
THIRD LETTER MEANS OF PERFORMANCE	S(SPEECH) P(PHONE, SOUND-POWER) I(INTERCOM) E(ELECTRICAL OR ELECTRONIC) T(TOUCH) V(VISUAL) F(FILED)
FOURTH LETTER DISPLAYED OR NOT	D(DISPLAYED) BLANK(NOT DISPLAYED)
FIFTH LETTER INVERSE MEANING	G(GO, YES NORMAL, ETC.) N(NO-GO, NO, ABNORMAL. ETC.)

It is anticipated that these behavior codes would be included, at periodic intervals on the printout, to reduce memorization and human error.

Figure 28 represents the output of either a time-line from stored data or simulation run in a proposed fixed format.

Figure 29 is the same information with the addition of heading and columnar lines drawn to show the sequence of operation and interrelated man or equipment operations necessary.

```
SUBSYSTEM-AN/SPS-000 RADAR                                      PAGE  1 OF 2        12A0101
COMPONENT-SIGNAL GENERATOR AX-424                               REVISION NO 00      12A0102
POSITION -MAINT TECH                                            DATE                12A0103
TASK NO 12A  TASK TITLE - ADJUST SIGNAL GENERATOR AX-424                            12A0104
                                                                                    12A0105
                                                                                    12A0106
C INTERRELATED OPERATION       TASK SEQUENCE         INDICATION OF              T  12A0201
H                                                  RESPONSE ADEQUACY            I  12A0202
N               BEHAVIOR     BEHAVIOR                                           M  12A0203
G                CODES        CODES                                             E  12A0204
                                                                                    12A0205
                                                                                    12A0206
 AN/SPS-000    HA       HA            ADJUSTS GAIN  CANNOT BE TURNED                12A0301
 MAINT TECH                           COUNTERCLOCK- FURTHER                         12A0302
 DEACTIVATES                          WISE TO STOP                                  12A0303
 AN/ABC-11                                                                          12A0304
 PREAMPLIFIER                                                                       12A0305
                                                                                    12A0306
                                                                                    12A0307
                        HA            ADJUSTS GAIN  17 TURNS FROM STOP              12A0401
                                      CLOCKWISE                                     12A0402
                                                                                    12A0403
                                                                                    12A0404
                        HA            ATTACHES      METER TS 35A                    12A0501
                                      METER TO TEST RESPONDS TO NULL                12A0502
                                      POINTS 3 AND4 PROBE                           12A0503
                                                                                    12A0504
                                                                                    12A0505
                        MAED          METER SHOWS   BETWEEN 50 AND 100              12A0601
                                      FREQUENCY     ON METER SCALE                  12A0602
                                                                                    12A0603
                                                                                    12A0604
                           HPV        REFERS TO                                     12A0701
                                      CALIBRATION                                   12A0702
                                      CHART ON TS-                                  12A0703
                                      35A PANEL                                     12A0704
                                                                                    12A0705
                                                                                    12A0706
                        HD            DECIDES AMT                                   12A0801
                                      AND DIRECTION                                 12A0802
                                      SIGNAL GENER-                                 12A0803
                                      ATOR FREQUEN-                                 12A0804
                                      CY MUST BE                                    12A0805
                                      CHANGED                                       12A0806
                                                                                    12A0807
                                                                                    12A0808
```

Figure 28. **Fixed Format Time-line Output from Stored Data on Simulation Run**

(Page 1 of 2)

		HA	ADJUSTS POT	12A0901
			22 COUNTER-	12A0902
			CLOCKWISE	12A0903
				12A0904
				12A0905
AN/SPS-[illegible]	HA	HA	REMOVES	12A1001
MAINT TECH			METER FROM	12A1002
ACTIVATES AN/			TP 3 AND 4	12A1003
ABC-11 PREAMP				12A1004
				12A1005
				12A1006
		END		12A1007

58*

Figure 28. Fixed Format Time-line Output from Stored Data on [illegible]ulation Run

(Page 2 of 2)

SUBSYSTEM-AN/SPS-[illegible] RADAR
COMPONENT-SIGNAL GENERATOR AX-424
POSITION -MAINT TECH
TASK NO 12A TASK TITLE - ADJUST SIGNAL GENERATOR AX-424

PAGE 1 OF 2
REVISION NO 00
DATE

INTERRELATED OPERATION	BEHAVIOR CODES	BEHAVIOR CODES	TASK SEQUENCE	INDICATION OF RESPONSE ADEQUACY	TIME
AN/SPS-[illegible] MAINT TECH DEACTIVATES AN/ABC-11 PREAMPLIFIER	HA	HA	ADJUST GAIN COUNTERCLOCKWISE TO STOP	CANNOT BE TURNED FURTHER	
		HA	ADJUSTS GAIN CLOCKWISE	17 TURNS FROM STOP	
		HA	ATTACHES METER TO TEST POINTS 3 AND4	METER TS 35A RESPONDS TO NULL PROBE	
		MAED	METER SHOWS FREQUENCY	BETWEEN 50 AND 100 ON METER SCALE	
		HPV	REFERS TO CALIBRATION CHART ON TS-35A PANEL		
		HD	DECIDES AMT AND DIRECTION SIGNAL GENERATOR FREQUENCY MUST BE CHANGED		

12A0101
12A0102
12A0103
12A0104
12A0105
12A0106
12A0201
12A0202
12A0203
12A0204
12A0205
12A0206
12A0301
12A0302
12A0303
12A0304
12A0305
12A0306
12A0307
12A0401
12A0402
12A0403
12A0404
12A0501
12A0502
12A0503
12A0504
12A0505
12A0601
12A0602
12A0603
12A0604
12A0701
12A0702
12A0703
12A0704
12A0705
12A0706
12A0801
12A0802
12A0803
12A0804
12A0805
12A0806
12A0807
12A0808

Figure 29. Fixed Format Time-line Output from Stored Data on Simulation Run With Header and Columnar Lines

(Page 1 of 2)

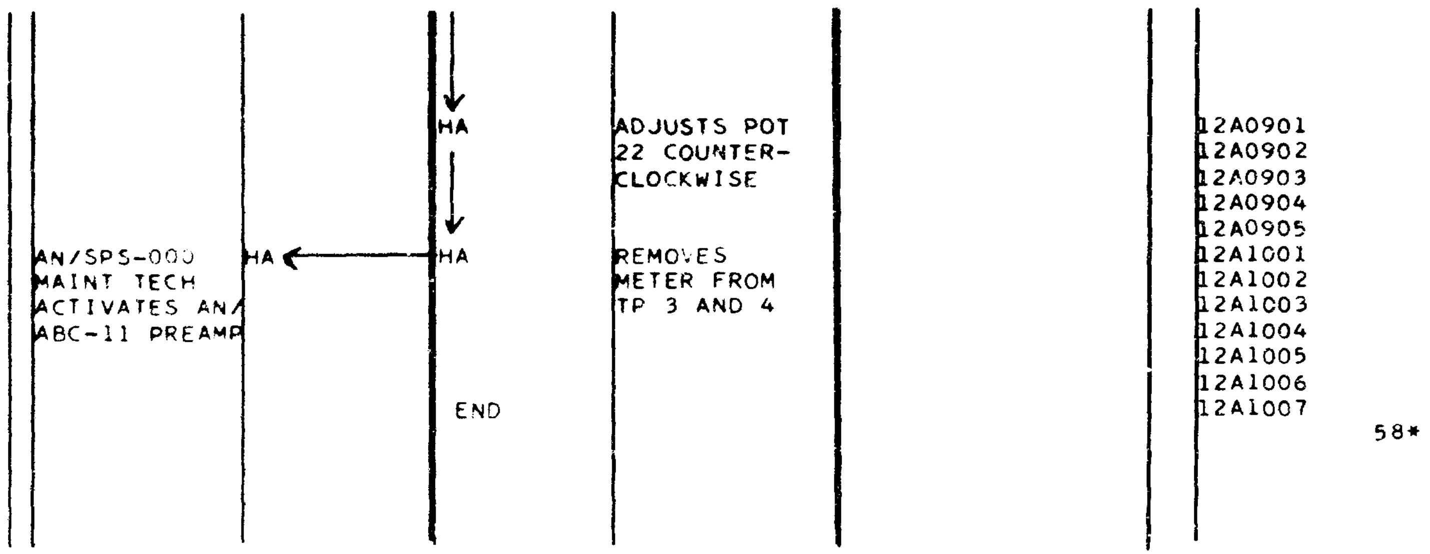


Figure 29. Fixed Format Time-Line Output from Stored Dat on Simulation Run With Header and Columnar Lines

(Page 2 of 2)

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5. AUTHOR(S) (First name, middle initial, last name)
Albert T. Tulley
George R. Meyer
Robert G. Oller
Phyllis J. Mitchell
Sue E. Reardon
Lawrence E. Reed - Air Force Human Resources Lab.

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13. ABSTRACT

Research leading to the application and implementation of techniques for computer handling of human factors task data generated in support of aerospace system development programs is discussed. The technique development is based on the assumption that a user-oriented computerized data handling system will help draw human factors specialists closer to needed data. The application of these techniques should reduce the problem of data accessibility and allow more effective use of data in the system design and development process. A computerized data handling system to store, selectively retrieve, and process human factors data in a user-oriented environment was implemented through a Pilot Study Experimental System (PSES). This experimental system provided the primary means for evaluating the research results. This report discusses the development process of the PSES, the computer software used by the PSES, data classification techniques, and vocabulary controls. Consideration is also given to the feasibility of providing (1) analytic and simulation tools in a user-oriented environment, (2) current awareness notification of data entries, and (3) an advanced and sophisticated classification scheme for identifying functional relationships.

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Data classification						
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